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Artificial Shades for Livestock in Hot Climates *C. F. Kelly and N. R. Ittner*

Recent Results of Irrigation Research in Georgia *J. R. Carreker and W. J. Liddell*

Direct Engine-Driven Power Take-off for Farm Machines *F. N. G. Kranick, A. W. Lavers, L. A. Gilmer, D. W. Innes, Elmer McCormick*

The Use of Supplemental Heat in Mow Hay Drying *R. B. Davis, Jr. and G. E. Barlow, Jr.*

The Design of a Terrace System from Hydrologic Data *Dwight D. Smith*

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RAYMOND OLNEY
Editor and Business Manager

EDITORIAL

Farm Hand Tools

THIS proposition might start an argument, but it has occurred to us that the modern American farmer should have around his place only a practical minimum of hand-farming tools.

We like good hand tools and good hand-tool craftsmanship, for jobs which cannot be done more satisfactorily with larger power-production machinery. But they can be a temptation to delay mechanization justified by the farmer's scale of operations; and to piddle away in hand operations time which might better be applied to directing the more productive work of power machinery. They can accumulate to the extent of a substantial investment. And more often than not they are kept in a dangerously poor state of repair and storage.

This leads us to suggest that a farmer should give as careful consideration to the purchase of a $2 hand hoe, shovel, pitchfork, or scythe as he would to ordering a $2,000 tractor, not because of the first cost but because the hand tool may hold down someone's productive capacity by more than the usual interest value of several thousand dollars. This sort of hand-power farming tool pegs the value of the user's time at somewhere around two or three cents per hour. And that is placing a murderously low value on human life.

On farms liberally supplied with tractor, truck, and electric power; in publications advocating efficient modern farming; in papers submitted to us for publication; and even in the advertising of various farm equipment manufacturers, we still see frequent unjustifiable hang-overs from the hand-method days.

Seeing farmers move tons of material to a machine which does a far more intricate job than carrying or transfer, suggests a question as to whether machines are being used as fully as practicable to relieve muscle as well as mental strain. Further, it suggests an incomplete analysis of opportunities to improve production efficiency.

Hand tools for proper farm maintenance of production equipment are another matter, and so are hand tools for recreational use.

Occasion for a farmer to do more than an incidental few minutes of hand hoeing, raking, mowing, pitching, shoveling, carrying, lifting, or climbing in his serious farming operations should be a warning to him. It should suggest that he see if some improvement can't be made by changing his equipment, the adjustment of his equipment, his methods and routings, the layout of his fields and buildings, his selection of crops and livestock, his scale of operations — or possibly his occupation!

The Second Challenge

AGRICULTURAL engineering has survived its initial challenge. It was the well-known pioneering, trail-blazing challenge to carry engineering beyond the bounds of precedent, against positive opposition, and with only the most elementary facilities, to an industry which scarcely realized that it needed or could profitably use engineering service.

It was a stage in which the difficulties of pioneer working conditions were offset, in some measure, by major opportunities to improve agricultural economy by application of even the most rudimentary engineering. Horse economy was not too hard to beat on large-acreage, heavy power jobs of plowing, grain harvesting, and threshing, even with wood and straw burners and "oilpulls." There was so much room for improvement in the production efficiency of large farms with good land that a little engineering went a long way.

What is the second challenge to agricultural engineering?

If we read the signs correctly, it may be summed up as a challenge to develop the more marginal opportunities for applying engineering to improve the agricultural economy.

It is a challenge to apply engineering to help more farmers make more of their lives and their land, whether that land is 10 acres or 10 thousand, level or on edge, dry or wet, rich or poor, here or in Timbuktu.

It is a challenge to the more technically difficult engineering of refining products, applications, and operations toward increasing usefulness under less favorable physical and economic conditions. Substantial progress has been made in meeting this challenge.

The bull-of-the-woods product of early agricultural engineering, which made good where strength and capacity paid dividends, has been refined and supplemented to provide a range of engineered products matched to minor as well as major opportunities to cut farm production costs, and to improve farm working and living conditions.

This has been progress toward a moving horizon. From our present position, the view of agricultural engineering's future is larger, clearer, and more studded with opportunities than ever before.

These more marginal opportunities are readily evident on the smaller farms, in less favorable locations, with fewer and smaller table-top fields and with wetter, drier, or less fertile land. They are evident in our silt-laden streams. They are evident on the subarctic and tropical frontiers of modern agriculture. They are evident in areas where technical progress of any kind awaits food production above the subsistence level. They are evident in the unskilled and semiskilled routine jobs still done by hand and by muscle power, on our most efficient and best-equipped farms. And in the jobs not being done which might be done profitably if suitable equipment were available.

The development of these more marginal opportunities is a challenge to advanced precision engineering. It means close tolerance work in the material, shape, size, and performance of mechanical, structural, electrical and hydraulic devices, which is already common practice. It also means some close figuring as to the economic feasibility of proposed refinements and new designs in these devices; and in matching them to the capabilities of the farmer, his land, capital, markets, and operating setup.

There is a tremendous field of engineering service in helping the world's farmers take continuing small steps forward from their respective present positions in production efficiency.

Defining the Engineer

A NEW, short, and useful definition of an engineer is suggested in an address by Arthur W. Turner at the recent dedication of the new agricultural engineering building at Michigan State College. Here it is:

"An engineer is one who takes less for granted than most of his fellow men."

While this definition is obviously incomplete, the "taking less for granted" which it emphasizes is a primary factor in the mental makeup and outlook of the engineer. It favors the sound direction and productive value of his efforts. It helps him to avoid fruitless thinking and talking in unqualified terms, about inaccurate and misleading generalities. It keeps him working toward increasing knowledge of and harmony with the laws of nature.

The engineer clearly indicates to himself and others the factors in a problem which he believes he can or must take for granted, for the time being. He limits his assumptions to those which will serve his purpose, pending the development of further information.

Among all the significant fields of human endeavor, agriculture has perhaps been most afflicted by the human weakness for taking things for granted.

About all that the agricultural engineer can safely take for granted is this. He must work in harmony with the laws of nature, including some which still remain to be discovered by fundamental research, and some which might be more accurately interpreted, and applied with more ingenuity than at present.

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No. 1C3, third "Caterpillar" Diesel built, went to work for Oahu Sugar Co., Ltd., Waipahu, Hawaii, November 7, 1931. Through the years, No. 1C3's regular jobs have been deep subsoiling, heavy harrowing and hauling trains of loaded cane cars. For the past couple of years, No. 1C3 has carried a mounted furrower-cane planter—serving on planting duty. By November, 1947, No. 1C3 had done 43,683 hours of heavy work—has had only two complete overhauls in its busy life—and is still at work.

There are younger "Caterpillar" Diesel Tractors that have done more hours of work than any of the first three. But none can more forcibly prove the basic soundness of the original "Caterpillar" Diesel design. None can more dramatically suggest what dependability and long, profitable working life "Caterpillar" builds into Diesels today—after nearly two decades of world leadership in Diesel design and manufacture!

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AGRICULTURAL ENGINEERING

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Artificial Shades for Livestock in Hot Climates

By C. F. Kelly and N. R. Ittner

MEMBER A.S.A.E.

A CO-OPERATIVE study of the environmental factors influencing the development, production and health of animals in warm climates was initiated in 1946 by the University of California and the Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Department of Agriculture. The heat production and efficiency of use of feed and water by hogs is being investigated under controlled environmental conditions in the psychrometric chamber on the College of Agriculture campus at Davis. The effect of various types of shades on the weight gains, physiological reactions, and health of beef cattle is being studied at the Meloland Field Station near El Centro in the Imperial Valley of California. This latter phase of the project will be discussed in this paper.

The weather of the Imperial Valley is well suited to a study of this type. An average monthly mean temperature of about 75 F (degrees Fahrenheit) is considered the upper limit which does not cause significant heat depression in temperate zone cattle. Imperial Valley's mean monthly temperatures are about 75 F for approximately 6 mo of the year, exceed 85 F for nearly 4 mo, and reach 90 F for 2 mo. June and part of July are dry and the nights rather comfortable. From about July 15 to September 20, the prevailing winds are from the south and southeast and bring in considerable moist air from the Gulf of Lower California. It is unfortunate that, when the humidity increases during this time, the night temperatures also rise, due to the greater back radiation from water vapor. Few nights during the second period drop below 70 F and the duration of time at these lower temperatures (70 to 80 F) is seldom more than 4 hr. Such conditions are oppressive to animals as well as to human beings.

Since environmental factors are considered to be of primary importance in summer livestock management problems, weather data for April to November, 1946 are presented in Fig. 1. Except for minor variations, the trends are typical of the longtime average.

From the engineering standpoint the problem of hot weather comfort for animals can be considered as a problem in heat transfer. The animal, to put on weight or even to maintain its weight, must consume large amounts of feed, part of which is used to build up body tissues, but the greater part of which is eventually discarded to the environment in heat, feces, and urine. It is estimated that, with cattle on full feed, from 20 to 30 per cent of the gross energy of the feed is dissipated as heat[1,2*]. As the environmental temperature increases, the animal's surface temperature also increases, but at a slower rate. The difference between the animal's surface temperature and the temperature of the air and the surroundings then becomes less and less, and it becomes more difficult to lose, by radiation and convection, the amount of heat necessary to retain a normal body temperature. The animal then, in an effort to keep a normal temperature, cuts down on its feed intake and increases its rate of respiration (thereby increasing the amount of heat lost by vaporization). Finally, the animal not finding it possible to dissipate all of the heat, a part of it must be stored, with a consequent increase in body temperature. The animal is then in an abnormal condition and will cut down still more on its feed intake and rate of gain in weight.

Of the four avenues of heat transfer available to the animal for cooling itself — conduction, convection, radiation, and evaporation — it seems that incoming radiation can be changed most easily by artificial means, such as shades. Increasing heat loss by convection involves increasing the velocity of or cooling the air, an expensive process. Increasing the velocity is of no benefit unless the animal's surface temperature is definitely higher than the air temperature.

Increasing heat loss by evaporation from the skin by using sprays is being investigated and will be discussed later in this paper.

Little heat can be lost by conduction to the ground from a standing animal, because of the small area contacting the ground or floor.

In the spring of 1947 five types of shelters were constructed at Meloland Field Station by the animal science division of the University of California, to provide shade for animals. Four of these shades, each 16x24 ft and 10 ft high at the eaves, were for the purpose of testing the effectiveness of various materials in cutting off solar radiation. The fifth shade was of aluminum and was used to shade the working space in the corral, the squeeze chute, scale, etc. The roofs are gable with about an 18-in rise. A brief description of each follows:

1 Wood slat shade. The roof is of 1x10-in boards spaced 1 in apart. The cracks run east and west. The floor is dirt.

2 Hay-covered shade. The roof is of about 6 in of coarse hay held in place between two layers of woven wire fencing. The floor under this shade is of concrete, with lines of 4-in drainage tile extending from end to end, each end opening into a concrete gutter. These tile lines are about 15 in on centers and about 7 in below the upper surface of the concrete.

3 Aluminum shade. The roof is of commercial standing-seam aluminum sheets. The floor is of concrete, provided with a 2-in drain in one corner. Overhead, down the center of the shade, are several spray heads which may be used to produce a fine spray under the shade.

This paper was presented at a meeting of the Pacific Coast Section of the American Society of Agricultural Engineers, at Yuma, Arizona, February 1948.

C. F. KELLY is agricultural engineer (BPISAE), U. S. Department of Agriculture, Davis, Calif., and N. R. ITTNER is associate in animal husbandry, California Agricultural Experiment Station, El Centro, Calif.

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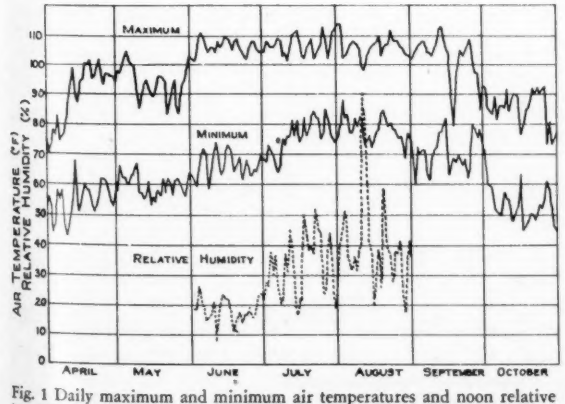


Fig. 1 Daily maximum and minimum air temperatures and noon relative humidities at El Centro, Calif. during period April to November, 1946

*Superscript numbers refer to appended references.

4 Galvanized iron shade. The roof is of old, corroded corrugated galvanized sheet iron, and the floor of dirt.

In June, 1947, before animals were available for the experiment, the intensity of radiation under each shade was compared with that from the unshaded sky and sun by means of a flat-plate radiometer. This is an instrument for measuring the total solar and sky energy incident upon a flat surface, developed by the illumination laboratory at the University of California at Berkeley, at the request of Dr. F. A. Brooks, for use in this project. The instrument was held 3 ft above the ground, at what would be about the center of a standing cow, and readings made on both the upper and lower hemispheres. The observations covered a period of several hours during the hottest part of the day. When measuring the radiation under a shade, the instrument was held at the center of the shadow. From 10 a.m. to 2 p.m. the radiation from the upper hemisphere was reduced 65 per cent by the solid shades (galvanized iron, aluminum, and hay covered), and 55 per cent by the wood slat shade. This agrees well with the findings of workers in Africa[3]. There was a slight difference in the amount of energy reaching the flat plate under the various shades. For instance, at 12 noon, when the air temperature was 99 F, the energy incident on the instrument under the hay shade was 181 Btu/hr/sq ft; under the aluminum shade, 190; under the galvanized shade 193, and under the wood slat shade, 223. At this time the total solar and sky radiation, including incoming long-wave atmospheric radiation, amounted to 527 Btu/hr/sq ft. In other words, the hay covered shade cut off 1.7 per cent more of the solar energy than did the aluminum shade, 2.3 per cent more than the galvanized iron, and 8 per cent more than the wood slat shade.

It was found that shades also reduced the radiation from the lower hemisphere, or the ground, although not to as great an extent. At 12 noon, when the ground radiation, in the sun, amounted to 242 Btu/hr/sq ft, the ground radiation under the solid shades averaged about 173 Btu/hr/sq ft, a reduction of 28 per cent. Again there was a slight difference noted in the effect of the various shades. The hay and aluminum shades reduced the ground radiation 28 per cent, the galvanized iron 27 per cent, and the wood slat shade 22 per cent. It should be noted that the sprays were not in operation under the aluminum shade at the time of these observations, and that the ground or floor under all shades was dry. Some of the differences in ground radiation, however, may be attributed to differences in material of floor construction.

These tests indicated that a more detailed study of radiation effects under the shades would be necessary to bring out the differences between the various materials of construction. In August qualitive measurements of radiation from the zenith and several angles below the zenith, as well as from several angles in the lower hemisphere, were made with a Hardy dermal radiometer[4]. This instrument included in its view an angle of only 16 deg, rather than the entire hemisphere, as did the flat plate radiometer. The results of the "scanning" of the hemispheres are shown in Fig. 2 for each of the shades. As with the flat plate radiometer, the instrument was held about 3 ft above the ground, at the center of the shadow. The air temperature was 95 F. The sprays under the aluminum shade were cut off, but the concrete floor was wet.

As shown by Fig. 2, this instrument indicated a slightly different order of efficiency of the several shades in cutting off solar radiation, namely, (1) aluminum, (2) hay, (3) wood slat, and (4) galvanized iron.

While the animal standing in the shadow of a shade is protected from the direct rays of the sun, it is still receiving and giving energy from and to the surroundings, depending on its surface temperature and emissivity, and the temperature and emissivity of the surroundings. "Emissivity" is defined

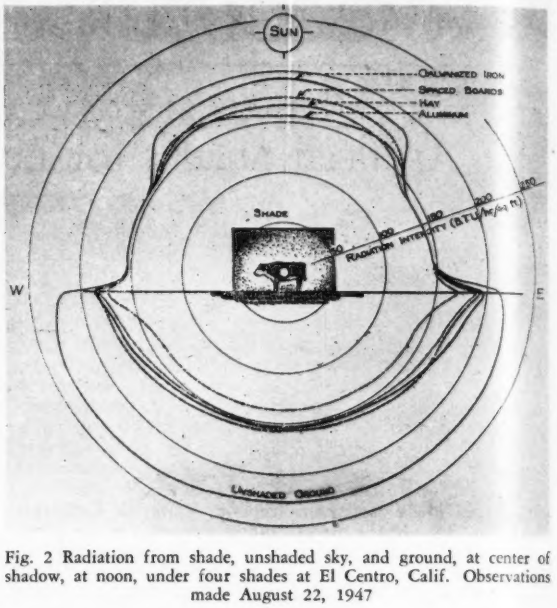


Fig. 2 Radiation from shade, unshaded sky, and ground, at center of shadow, at noon, under four shades at El Centro, Calif. Observations made August 22, 1947

as the "ratio of the total emissive power of any body to the total emissive power of a black body, at the same temperature"[5]. The roof of the shade is usually above the air temperature, during the daytime. Observations in August, 1947, indicated that at midday, at times when the air temperature was about 100 F, the temperature of the underside of the El Centro shades (the side radiating to the animals standing in its shadow) averaged, for the galvanized iron, 26 F above air temperature; for the aluminum shade, 10 F; for the wood shade, 9 F, and for the hay shade, 5 F. The original data are given in Table 1 along with the emissive power as obtained by the Hardy radiometer. Using these data the averaged emissivity of the wood surface, as calculated by the Stefan-Boltzmann formula, was 0.98, for hay 0.94, galvanized iron 0.90, and aluminum 0.82. These emissivities are high when compared with handbook data, but in general the emissivity, especially of the metals, will increase with exposure and age.

The value of each material in the shades in cutting off solar and sky radiation was also determined by the reactions of cattle sheltered under them. Between July 23 and September 15, 1947, three Hereford heifers were placed in the pens surrounding each of the four experimental shades and their physiological reactions, feed consumption, and weight gains observed. They were fed fair quality alfalfa hay, a little cottonseed meal, salt, and water. Although the length of time was short, the number of animals small, and most differences between pens not statistically significant, almost all differences followed the same pattern. That is, those animals under the hay and aluminum shades appeared cooler and more comfortable than those under the wood slat and galvanized iron

TABLE 1. TEMPERATURE AND EMISSIVE POWER OF UNDER SURFACES OF SHADES COVERED WITH HAY, WOOD, GALVANIZED IRON, AND ALUMINUM, AT EL CENTRO, CALIF.

Date (1947)	Time	Air temp, deg F	Hay covered		Wood covered		Galv iron covered		Aluminum covered	
			Temp, deg. F	E*	Temp, deg. F	E*	Temp, deg. F	E*	Temp, deg. F	E*
June 25	1:35 p.m.	100	101	—	104	—	122	—	112	—
	2:30 p.m.	98	104	—	106	—	120	—	—	—
Aug. 19	11:10 a.m.	102	107	174	112	190	139	194	127	172
	2:40 p.m.	108	114	160	115	181	125	180	124	166
Aug. 22	12:00 noon	95	101	167	110	174	128	187	118	156

* Emissive power (Btu/hr/ sq ft) as determined by Hardy radiometer.

NOTE: Air temperature obtained by No. 30 BS gage shielded copper constantan thermocouple and surface temperatures by touch thermocouple of same size wire.

shades. The normal body temperature of a cow is between 101 and 102 F, while the comfort zone for respiration rate is between 20 and 50 per minute. Between July 23 and September 3, 31 sets of body temperatures were taken on these heifers. Unfortunately there was a wild heifer under the galvanized iron shade and only a few body temperatures were taken on this group. Body temperature averages were as follows: hay roof, 103.0 F; aluminum roof, 103.3 F, and wood slat roof, 103.5 F. The difference in respiration rates of the four pens was negligible, all averaging about 90 per minute.

The average rate of gain for all animals was poor, being 0.48 lb per day for the 55-day test period, but the animals under the hay and aluminum shades again did a little better than those under the other two shades. Feed consumption followed the same pattern as the rates of gain. Salt consumption was normal.

The heifers under the hay-covered shade and wood slat shade are shown in Figs. 3 and 4.

The showers under the aluminum shade undoubtedly affected the results of this experiment as far as the reaction of the cattle are concerned. From July 28 to August 14, a fine "mist" spray from three shower heads, under 30 psi pressure, was used. However, the animals made little use of it and did not appear to be getting any beneficial effects from either the sprays or the wet floor. From August 14 to September 14 only one shower head was used, but the hole was enlarged to give a coarse spray and the head brought down to within 6 ft of the floor. These fine and coarse sprays would be comparable to the fine and coarse sprays from an ordinary adjustable garden nozzle with the hydrant only one-fourth open.

Apparently cattle have to learn the value of a sprinkler. After changing to the coarse spray, they began to make more use of it, and towards the end of the test one animal was using the shower as much as 3 hrs a day. A view of this animal standing in full sun, with the air temperature 109 F, in order to take advantage of the spray, is shown in Fig. 5. Near the end of the experiment the heifers were wet down with a garden hose several times, and after this "lesson" they seemed to use the shower more than they did before. When using the mist spray, the animals got only a superficial dampening, but with the coarse spray they were wet to the skin. This soaking caused a decided drop in respiration rates and body temperatures. Wet animals quite often had a body temperature 2 to 3 F lower than dry animals and respiration rate drops of 20 or more per minute were noted a number of times a half hour after the cattle got wet.

Even when night temperatures did not drop below 80 F the heifers would not use the showers at night. Their use was confined to the late morning and most of the afternoon.

The radiation values in Fig. 2 show that the ground radiation is of importance and must be considered in the problem of animal comfort in warm climates. The flat plate radiometer which integrates the energy from an entire hemisphere falling on a flat surface, indicated that in August, near midday, when the solar and sky radiation was at a maximum, the lower hemisphere radiation was from 40 to 50 per cent that of the upper hemisphere. This was for areas of unvegetated hard ground away from the shade, no part of which had been in shadow during the day. The air velocity varied from 150 to 200 fpm. Under the shades the radiation from the lower hemisphere, at the same time of day, was about the same as from the upper hemisphere. The lowering of the temperature of the concrete under the aluminum shade was of marked benefit in lowering the amount of radiation, as shown in Fig. 2. Some benefit might also be derived from vertical shades.

It is well known that the air temperature over a green field during the daytime will be lower than over a black plowed field. We found that on two adjacent plots each 200 ft square the air temperature over alfalfa averaged 5 F lower at midday than over plowed ground. This difference was reflected in the values for radiation, the lower hemisphere radiation over the alfalfa plot being 30 per cent as great as the upper hemisphere or sky and solar radiation, but over the plowed ground amounting to 40 per cent, as measured by the flat plate radiometer.

While it would be impractical to maintain green vegetation under and immediately adjacent to an animal shade, unvegetated ground also varies in temperature by reason of differences in thermal conductivity, density, and other characteristics, and it may be possible to increase the animals' comfort by selection of the proper type of ground surface. Observations of soil surface temperatures with a touch thermocouple at El Centro in August, 1947, showed that there are considerable differences in areas only a few feet apart. For instance, at 11 a.m., on a day when the air temperature was only 89 F, the following temperatures were observed in the sun:

Hard ground, tramped by cattle	124 F
Hard ground, in road	129 F
Soft ground, not tramped by cattle	132 F
Dry rotted manure in feed lot	148 F

Up to the present we have been considering the effect of the shade upon the radiation intensity and air temperature — in other words, upon the environment of the animal. How-

TABLE 2. SURFACE TEMPERATURES OF CURLY HAIRED YEARLING HEREFORDS IN SUN AND IN SHADOW OF HAY COVERED SHADE. AIR TEMPERATURE, 100 F

Position on animal	Surface temperature, in deg F	
	Animal in sun	Animal in shade
Back	124	101
"	119	104
"	125	104
"	133	104
"	—	102
"	—	103
"	—	105
Side (away from sun)	114	104
"	—	105
"	—	107
"	—	101
Side (towards sun)	131	—
Belly	109	—

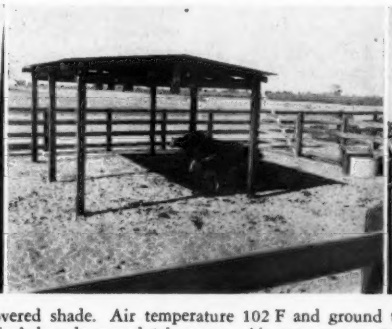


Fig. 3 (*Left*) Cattle lying in shadow of hay-covered shade. Air temperature 102 F and ground temperature in shadow 99 F • Fig. 4 (*Center*) Cattle standing under shade covered with 1x10-inch boards spaced 1 in apart. Air temperature 103 F and ground temperature in shadow 104 F. In unshaded strips between board shadows ground temperature was 148 F. High ground temperature may be reason for cattle not lying down • Fig. 5 (*Right*) Yearling Hereford standing in sun, with air temperature at 109 F, in order to take advantage of spray

ever, the heat loss by convection and radiation in a given environment is also controlled by the surface temperature of the animal. The animal's surface temperature changes with the environment, acting as a method of body heat regulation. Observations were made of the surface temperature of the Herefords at high air temperatures both in the sun and in shadow with touch thermocouple and with Hardy radiometer. Data from curly-haired yearlings obtained with touch thermocouple is given in Table 2. The air temperature was 100 F, with very little air movement. The rectal temperature of the animal in the sun was 104.3 F and the rate of respiration 108 per minute. Observations on the cattle in the shade with the radiometer indicated temperatures of the same magnitude, and touch thermocouple observations taken at Davis also support these data.

A few readings were made on slick areas of the coat of cattle standing in the sun, and it was found that the slick area temperatures averaged 105 F as compared to 124 F, 119 F etc., for the curly areas. This difference between slick and curly areas did not show up on the cattle under the shades. We did not make enough observations to determine the effect of hair color on the surface temperature.

It is possible to approximate the heat interchange between an animal and its environment by using some of the data supplied herewith. In Fig. 6 an animal is shown under a shade and also in direct sun, the radiation, except from directly overhead, being indicated by the contour lines. We have a flat plate radiometer observation for the upper hemisphere, however, and can use this value for the upper surface exchange. The animal surface temperatures are given in Table 2. The El Centro heifers weighed about 750 lb and had a surface area of around 42 sq ft[6]. Because of the differences in temperatures over various parts of the animal's surface and to variations in intensity of radiation over the sky and lower hemisphere, it is helpful to break the animal's surface up into three parts — the upper surface or back, the lower surface or belly, and the sides plus the ends. In Fig. 6 the back area is indicated by quadrants I, the belly by quadrants III and the sides and ends by quadrants II and IV. The area of the back in this example is taken as 7 sq ft, of the belly as 7 sq ft, and of the side and ends as 26 sq ft. Since part of the animal's surface such as the areas between the legs, inside the ears, etc., will be radiating to surfaces at the same temperature and the net exchange will be zero, 2 sq ft are considered as non-radiating. The heat loss by radiation from any part of the cow's surface is given by the equation:

$$Q_r = A\,(\sigma\, p_1\, T^4 - I)$$

where A = area of surface being considered in square feet

σ = Stefan-Boltzmann constant 0.173×10^{-8}

p_1 = emissivity of cow, 0.93

T = absolute temperature of cow's surface (deg F)

I = radiation from environment or surroundings (Btu/hr/sq ft).

We can obtain I or the radiation from the surroundings on each area of the cow by averaging the values from Fig. 6. Although the emissivity of a cow's surface is not exactly known, many observations on hogs at Davis have indicated the value of 0.93 to be about correct for hair-covered animals. The results of calculations for each area of the cow's surface (back, two sides, and belly) are summarized in Table 3 for both shaded and unshaded conditions. Totaling the next exchange by radiation we find that the unshaded cow is receiving 2423 Btu more per hour than she is emitting, and that the cow under the shade is emitting 340 more Btu per hour than she is receiving. It should be remembered that the situation has been idealized by considered the cow as having flat surfaces. The negative signs (—) in the table indicate heat movement into the cow and the plus signs (+) heat movement from the cow.

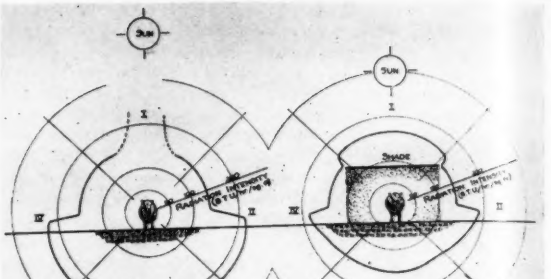


Fig. 6 Irradiation (Btu/hr sq ft) of (A) unshaded cow and (B) shaded cow, from upper and lower hemisphere. Air temperature, 100 F

An approximation of heat exchanged by convection can also be made. Heat loss from a surface by convection is given by the equation:

$$Q_c = f_c\, A\, (t_1 - t_2)$$

where f_c = film conductance (Btu/hr/sq ft/deg F)

A = area of surface in square feet

$t_1 - t_2$ = difference in temperature between air and cow's surface (deg F).

The experiments with hogs at Davis have indicated a film conductance of 2.6 for animals in an environment of 100 F, with low air movement. For our approximation we feel this figure is applicable because of the similarity of the surfaces and conditions. The animal's surface area for convection is 42 sq ft and the average surface temperature for the animal in the sun 117 F and in the shade 104 F. Air temperature is 100 F. By calculation the convection loss from the cow in the sun is 1856 Btu/hr and from the shaded cow 437 Btu/hr. The reason for the greater loss from the cow in the sun is of course the greater surface temperature.

The radiation and convection exchange can be summarized as follows:

	Unshaded Cow	*Shaded Cow*
Heat exchange by radiation, Btu/hr	−2423	+340
Heat exchange by convection, Btu/hr	+1856	+437
	− 567	+777

The negative sign (−) indicates heat movement into the cow and the plus (+) sign movement away from the cow. The unshaded animal must lose a total of 1344 Btu more heat per hour than the shaded heifer, by vaporization (the sum of 567 and 777). This is equivalent to the evaporation of 1.3 lb of water. (*Continued on page 250*)

TABLE 3. EXAMPLE OF HEAT EXCHANGE BY RADIATION BETWEEN SURROUNDINGS AND BOTH SHADED AND UNSHADED COWS WEIGHING 750 LB. AIR TEMPERATURE 100 F AND WIND VELOCITY LESS THAN ONE MILE PER HOUR

	Unshaded Cow			Shaded Cow		
Quadrant	I	II & IV	III	I	II & IV	III
Position on cow	Back	Side	Belly	Back	Side	Belly
Surface area, sq ft	7	26	7	7	26	7
Temperature of cow's surface, deg F	130	115	109	104	104	104
Rate of radiation from cow, Btu/hr/ sq ft	194	175	167	162	162	162
Rate of radiation from surroundings, Btu/hr/ sq ft	440*	185	230	160	150	160
Net rate of exchange, Btu/hr/ sq ft	−246	−10	−63	+2	+12	+2
Net exchange for area	−1722	−260	−441	+14	+312	+14

* This observation by flat plate radiometer.

Results of Irrigation Research in Georgia — Part I

By John R. Carreker and W. J. Liddell
MEMBER A.S.A.E. MEMBER A.S.A.E.

INTEREST among Georgia farmers in supplemental irrigation has sharply increased during recent years. Several things have brought this about, chief of which are (1) the detrimental effects of short drought periods during the growing season, (2) the availability of improved portable irrigation equipment, and (3) the desire of farmers to eliminate weather risks in the production of high-income farm products.

There has been relatively little research in supplemental irrigation in the southeastern area; and in order to answer many of the inquiries, considerable investigation is necessary. In an attempt to obtain information for farmers, agricultural workers, and others who may be interested, the agricultural engineering department of the University of Georgia, jointly with the research division of the Soil Conservation Service, U. S. Department of Agriculture, established a research project in supplemental irrigation in 1946.

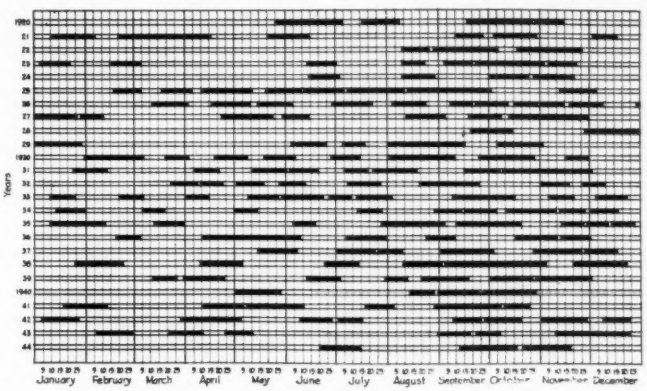


Fig. 1 This graph shows drought periods in the 25-yr period (1920-44) at Athens, Ga. The black strips indicate drought periods

The general objective of this research project is to determine the conditions under which the production of field crops, vegetables, pastures, orchards, and vineyards may be increased through the use of supplemental irrigation, and to devise methods and equipment which will meet the requirements of such conditions. This project, as the general objective indicates, is comprehensive and encompasses the major problems relating to the agriculture of the southeastern region in so far as it may be affected by supplemental irrigation. A program of research, both basic and applied, directed toward the attainment of the major objective, has been developed to consider specific phases of the major problem.

The specific investigations now being conducted include:

1 *Climatological Studies* to determine the interrelation between intensity and amount of rainfall, temperature, and the occurrence of soil moisture deficiencies or drought periods in Georgia.

2 *Irrigation Water Resources,* both surface and underground, to determine the quality, availability, and methods of storage and conservation, and to evaluate the hydrologic and hydraulic factors affecting same.

3 *A Survey of Systems, Methods, and Equipment* currently used in irrigation installations in Georgia and other southeastern states to find the types of systems now being used, the methods of irrigation followed, the efficiency of current systems, and the effects of supplemental irrigation upon soil loss and crop yield.

4 *Supplemental Irrigation of Pastures* to determine its effect upon the production of pasture herbage, animal growth and milk produced, and the amount of grazing afforded.

5 *Supplemental Irrigation of Field Crops* to determine the extent to which yields can be profitably increased with additional moisture, as indicated by the effect upon plant growth and crop yield.

6 *Supplemental Irrigation of Vegetable Crops* to determine if the conditions of soil moisture most favorable to the growth and production of vegetable crops can be better and more profitably produced and maintained in the soil artificially by supplemental irrigation than by natural means alone as indicated by the effect upon crop yields.

The first phase of this project was a detailed study of rainfall records for the past 25 years at 6 locations in Georgia. Drought periods were studied in detail from these records. A drought was described as "A period of 14 days or more in which there is not one-quarter of an inch of rainfall in any one 24-hr period."* The drought periods for 1920-44, 25-yr period at Athens, Ga., are shown in Fig. 1.

Analyses of these periods are given in Tables 1 and 2. From Table 1 it is seen that drought periods are likely to occur during every month of the year. Those in the winter months are fewest and usually are of more benefit than detriment to the farmer. During the entire growing season of March through November, there is a 50 per cent, or greater, risk of a drought any year.

This is the first part of a combination of two papers presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1947, and at a meeting of the Southeast Section of the A.S.A.E. at Washington, D.C., February, 1948.

JOHN R. CARREKER and W. J. LIDDELL are agricultural engineers employed cooperatively by the Soil Conservation Service (Research), U. S. Department of Agriculture, and the agricultural engineering department, University of Georgia, Athens.

TABLE 1 - DROUGHT FREQUENCY BY MONTHS AT ATHENS, GEORGIA

MONTH	NUMBER OF YEARS WITH DROUGHT PERIODS IN 25 YEARS	AVERAGE FREQUENCY
January	8	1 EVERY 3 YEARS
February	10	2 EVERY 5 YEARS
March	7	2 EVERY 7 YEARS
April	13	1 EVERY 2 YEARS
May	14	1 EVERY 2 YEARS
June	14	1 EVERY 2 YEARS
July	16	2 EVERY 3 YEARS
August	14	1 EVERY 2 YEARS
September	24	1 EVERY 1 YEARS
October	21	4 EVERY 5 YEARS
November	22	8 EVERY 9 YEARS
December	12	1 EVERY 2 YEARS

* Preliminary Climatological Study of Relationship Between Amount of Rainfall and Drought Occurrences in Georgia, by Lee D. Dumm and W. J. Liddell. Annual Report of Research and Investigational Activities, College of Agriculture, University of Georgia, for the year ending June 30, 1946.

TABLE 2 - DROUGHT OCCURRENCES AND DURATION BY SEASONS AT ATHENS, GEORGIA

SEASON	DURATION	NUMBER TIMES IN 25 YEARS	AVERAGE FREQUENCY
Spring	2 WEEKS	34	4 EVERY 3 YEARS
	4 WEEKS	5	1 EVERY 5 YEARS
	6 WEEKS	1	1 EVERY 25 YEARS
Summer	2 WEEKS	43	5 EVERY 3 YEARS
	4 WEEKS	3	1 EVERY 8 YEARS
	6 WEEKS	2	1 EVERY 13 YEARS
Fall	2 WEEKS	57	7 EVERY 3 YEARS
	4 WEEKS	10	7 EVERY 9 YEARS
	6 WEEKS	7	2 EVERY 7 YEARS

Fig. 2 (*Top*) Portable irrigation pumping unit consisting of a four-cylinder, 17-hp, air-cooled gasoline engine, 2-in centrifugal pump, suction hose, and discharge hose equipped with quick-coupling attachment, all mounted on a surplus war bomb trailer • Fig. 3 (*Bottom*) Portable pipe with quick-coupling attachment and rotating sprinklers irrigating a pasture. The No. 10 cans are for checking the distribution of water

The frequency of droughts of 2, 4, and 6 weeks' duration is given in Table 2.

Those of 2 weeks' length are almost certain to occur more than once during the spring, summer, and fall seasons each year. Periods of 4 weeks without rain are expected on the average of once every 5 years in the spring, once every 8 years in the summer, and nearly every year (7 out of 9) in the fall.

Droughts of 6 weeks' duration may happen once in 25 years during the spring, once in 13 years in the summer, and 2 years out of 7 in the fall.

The foregoing discussion applies to the U. S. Weather Bureau rainfall data during 25 years ending in 1944 at Athens, Ga. Data from five other stations ranging from the seacoast at Savannah to the mountainous region at Dahlonega indicate fairly similar conditions. There are fewer drought periods in summer and more in winter at Savannah and through the Coastal Plain than at Athens. The total number expected is approximately the same.

These data clearly show that the lack of rainfall at strategic periods throughout the spring, summer, and fall is likely to be a limiting factor in maximum crop yields. It is common experience that spring droughts may cause reduced stands and sometimes require crops to be planted over. Dry spells in the summer frequently are the limiting factor in corn production, particularly in the northern half of the state. Growth of other crops is hampered at this time also. Fall vegetable production dependent on natural rainfall is seriously hindered. Permanent pastures frequently dry up and give limited grazing. The fall planting and growth of temporary grazing crops often meet with interference from lack of sufficient rainfall at the proper time.

It can be seen, therefore, that supplemental irrigation may be used to good advantage under certain conditions in the Southeast. There apparently is a fundamental reason underlying the increased desire of farmers for irrigation equipment. Much research and practical experience is needed, however, to determine the limits under which such equipment may be adapted to farm conditions.

Information and data were obtained on irrigation water resources from the U. S. Geological Survey, the State Department of Mines, Mining and Geology, and other sources. These studies showed that in the mountainous northern part of the state the everflowing small streams and rivers offer abundant water for irrigating the fields adjacent to these streams.

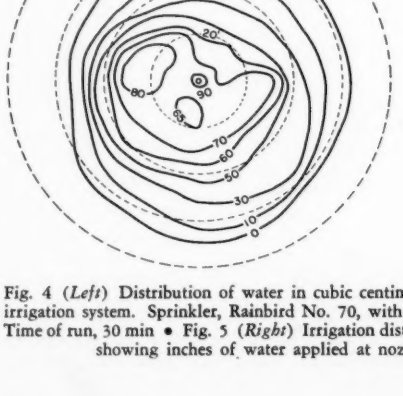
In the Piedmont belt through the central portion of the state, surface streams, ponds, and lakes may be used as sources of water. Many of the smaller streams, however, cease to flow during prolonged dry spells when irrigation water would be needed most. Therefore, impounded reservoirs would be required along the smaller streams. Base flow measurements of the larger streams indicate a dependable supply of approximately 0.5 cfs per square mile of drainage area.

Many sections of the Coastal Plain area comprising the lower half of the state are underlain with limestone deposits from 100 to 400 ft below the surface. These deposits may be tapped with deep wells for irrigation water. Artesian pressure in nearly all cases forces the water to within 60 ft of the surface. In some cases there are artesian flows at the surface with pressures up to 7 psi.

Surface streams, impounded reservoirs, and lakes also may be used extensively throughout the Coastal Plain area for sources of water.

The quality of the surface water throughout is sufficiently high to permit its use for irrigation. The underground water is also of good quality except in areas adjacent to the seacoast. There caution must be exercised not to have wells that might be contaminated with salt water from the ocean.

Surveys of irrigation systems installed showed a strong trend toward the use of portable quick-coupling pipe and rotating sprinkler heads on riser (*Continued on page 250*)



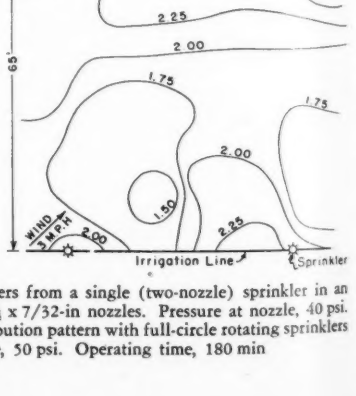


Fig. 4 (*Left*) Distribution of water in cubic centimeters from a single (two-nozzle) sprinkler in an irrigation system. Sprinkler, Rainbird No. 70, with ¼ x 7/32-in nozzles. Pressure at nozzle, 40 psi. Time of run, 30 min • Fig. 5 (*Right*) Irrigation distribution pattern with full-circle rotating sprinklers showing inches of water applied at nozzle, 50 psi. Operating time, 180 min

Direct Engine-Driven Power Take-Off

Discussion by Frank N. G. Kranick

THE direct engine-driven power take-off is not a recent development. In April, 1925, I presented a paper before the meeting of the Power and Machinery Division of the American Society of Agricultural Engineers, entitled "The Power Take-Off for Tractors." This paper, as published in AGRICULTURAL ENGINEERING for September, 1925, contained an illustration of the constant-running power take-off. It showed a track-type tractor, the belt pulley of which was mounted on the front end of the engine which served to convey power by means of a flat belt to a mower, also mounted in front of the tractor. This mower was operated by power directly from the engine and not through a transmission. Another illustration in the same article was of a mower mounted at the rear of a Fordson tractor, with power furnished from an extension to the worm shaft, which made the drive a function of the transmission.

At the time this paper was presented, I made a plea to the tractor industry for adoption of the power take-off, which was discussed at considerable length by engineers in the industry.

In November, 1926, I made a talk on the subject, "The General-Purpose Tractor," before the tractor and thresher department of what is now the Farm Equipment Institute. In addition to a market analysis presented, to show that there existed a ready market for nearly four million general-purpose tractors to sell at a price below $600, I listed in the specifications for such a tractor nine items which I considered to be essential features, in which I included the power take-off.

Some forty years ago in 1904 and 1905, a Frenchman, Albert Gougis, made a tractor with a constant-running power take-off to overcome difficulties in the field in harvesting down or lodged small grain with a binder, and trials held in 1906 showed this to be a very practical device. The unit was in actual use by its originator for ten or twelve years, and the tractor with its constant-running power take-off was on exhibition in the agricultural museum in Paris where I have actually seen it.

Some time ago my attention was called to a statement which appeared in an article, entitled "Horsepower Requirements of Power Take-Off Driven Combines," by C. G. E. Downing which appeared in AGRICULTURAL ENGINEERING for February, 1942, as follows: "It is clearly indicated from the results of these tests that some type of independent power take-off is essential on the combine or the tractor unit if satisfactory operation of this type of combine is to be secured under rolling land conditions."

The question I would put to you engineers at this point is: Just why does it take so long to provide a unit costing so little and with such great advantages for the farmer?

Discussion by A. W. Lavers

THE regular power take-off now used on all tractors was developed in 1923, as an attachment to tractors then in use. It was designed principally for driving grain binders requiring about 6½ hp. Soon this power take-off was available on all tractors, and then there came the request for a power take-off that would be driven independently, so, when the tractor was stopped, the power take-off would continue to run —also that would handle the full horsepower of the engine.

To furnish a power take-off of this type, of course, requires a major redesign or a new design of the tractor. In 1944, the Cockshutt Plow Company started development of its Model 30 tractor, and decided to incorporate in this design a direct engine-driven power take-off. In this design a sleeve is placed over the clutch shaft and a connection is made between the flywheel or the housing of the clutch to this sleeve, so that it will turn whenever the engine is running. A gear is placed on this sleeve back of the main clutch shifter mechanism, and this gear meshes with a gear which is attached to a shaft running back over the transmission of the tractor to the rear end. At this point another gear reduction is made and the power take-off clutch is placed on a countershaft. This is an overcenter clutch and is used in engaging or disengaging the power take-off. Another reduction is taken from this shaft down to the power take-off shaft where the proper location and speed is obtained. This unit is designed so that all but the sleeve and one gear at the front of the tractor can be sold as an extra, and be put into the tractor after it is assembled.

The unit has met with a great deal of success and to date all of the tractors sold by the Cockshutt Plow Company have been equipped with direct engine-driven power take-off, even though a regular power take-off is available. It is a very popular unit as it does away with the objections which were raised when the regular power take-off was used. Now tractors can be stopped either to change gears or for any other purpose, and the power take-off driven machine can be kept running, whereas with the old power take-off the machine would stop and in some cases clog, and it would be impossible to start without first cleaning it out. It is believed that had the direct engine-driven power take-off been available years ago there would be very few machines provided with auxiliary power units, as there would be no demand for this power.

There are various other designs which have been at least put on paper—one where a hollow shaft is used for the main transmission shaft, and through this shaft the power take-off shaft is run to the back of the tractor. The clutch is placed on this shaft right back of the flywheel, and gearing is used in the rear end in order to get the proper speed and location of the power take-off connecting shaft.

Another design which was worked on is placing a master clutch directly back of the engine, then a separate clutch for the tractor transmission which can be disengaged to stop the movement of the tractor. The master clutch when disengaged would stop everything. There are certain disadvantages to this type of power take-off as well as advantages.

No doubt more implements and trail-behind machines will be developed when the direct engine-driven power take-off is available on more tractors, as this unit will make the tractor a more useful all-purpose machine. The direct engine-driven power take-off can be classed as one of the important improvements developed for tractors during the past several years.

Discussion by L. A. Gilmer

THE advantages of the direct engine-driven power take-off are obvious for the majority of the more common power take-off driven machines, such as combines, corn pickers, and field ensilage harvesters. There are several other more or less special applications in which greatly improved performance may be expected from this type of power take-off.

One application which has bothered us for a considerable time has been the power take-off driven spray rig used in young orchards, berry bushes and vineyards. For several years we have experienced a rather insistent demand for an extremely slow travel speed on the order of ½ to ¾ mph to permit spraying while in motion. It was impossible to obtain this speed through a reduction in the engine speed because of the necessity of maintaining full power take-off speed. A gear reduction down to this speed at full engine speed almost was prohibitive. We believe the continuous power take-off will satisfactorily solve this particular problem in that the tractor can be stopped at each point for a sufficient time to spray a

These discussions were presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1947, as a contribution of the Power and Machinery Division.

FRANK N. G. KRANICK is a farm machinery consultant, Racine, Wisconsin.

A. W. LAVERS is owner, Lavers Engineering Co., Chicago, Ill.

L. A. GILMER is chief engineer, Charles City Works, The Oliver Corporation, Charles City, Iowa.

given area and can then be moved on to the next stop without the necessity of declutching and shifting the transmission into neutral.

Another application in which this power take-off will have a tremendous advantage is in pea harvesting where rear-mounted windrowers are used, and the tractor is driven in reverse for the cutting and windrowing operation. The advantage in this case is similar to that of any harvesting equipment in that the tractor can be stopped to permit the machine to clear itself, and the importance in this case is the saving in time, because this is probably the most critical element in the harvest of fresh peas.

At the outset of our work on this problem it was recognized that this type of power take-off obviously must cost considerably more than the old conventional type. It was also recognized that possibly this unit would not be required in all cases where a power take-off would be used, and therefore it would have to be possible to supply the conventional power take-off at a considerably lower cost in these cases. Another important consideration was that possibly 25 to 50 per cent of all machines, depending on territories and the size of power plant, would require no power take-off at all.

All of these factors pointed to the need for a unit that would not increase the basic cost of the tractor appreciably and that also was adaptable for the use of the conventional power take-off as well as the direct engine-driven type. Since certain of our models were scheduled for redesign anyway, it was possible to incorporate the hollow-shaft construction which we believe satisfies these conditions.

The power take-off drive shaft is splined to a hub which is bolted directly to the engine flywheel. This hub also acts as a pilot for the hollow clutch shaft which is splined to the main clutch disk hub in the conventional manner. The power take-off drive shaft passes through the hollow clutch shaft, the clutch shaft coupling and a hollow transmission input shaft and is supported approximately in the middle of its length by a plain bearing in the transmission case.

ADDITIONAL COSTS IN BASIC TRACTOR ARE SMALL

A 19-tooth involute spline is used for the clutch shaft and the transmission input shaft in order to keep the outside diameter as small as possible, while providing clearance inside for the power take-off drive shaft. The only penalty in the basic tractor is the additional cost of the hollow shaft over a solid shaft and addition of the power take-off drive hub bolted to the flywheel, which is supplied with all tractors.

In case it is found necessary in the future to supply the conventional power take-off at lower cost where the continuous type may not be required, it will be possible to couple a a drive shaft directly to the rear extension of the transmission input shaft. This will replace the long drive shaft which extends forward to the flywheel in this design.

The power take-off drive shaft passes through the rear main frame or final drive housing into the power take-off unit where it is splined to the power take-off clutch driving plates. The power take-off clutch is an overcenter double disk type of 8-in diameter. It is bolted to a mounting sleeve which supports the power take-off gear reduction pinion.

When the clutch is engaged, power is transmitted to the clutch mounting sleeve and in turn to the pinion which is splined to this sleeve. The pinion meshes continuously with the power take-off gear splined to the power take-off shaft, and this reduction provides the standard power take-off speed of 533 rpm, when the engine is running at its governed speed of 1600 rpm.

If the conventional power take-off is required, all of the clutch mechanism can be omitted and only the gear reduction unit would be used. The gears and the bearings supporting the clutch mounting sleeve and the power take-off shaft are lubricated by a self-contained oil supply within the power take-off unit. The bearing supporting the rear of the power take-off drive shaft in the clutch mounting sleeve is lubricated by gravity flow of oil that is thrown on the power take-off drive shaft from the tractor final drive mechanism. The power take-off clutch release bearing is lubricated by a grease fitting which is reached through an opening in the rear of the clutch cover. Oil is prevented from flowing from the final drive to the power take-off or from the power take-off to the final drive by means of a shielded bearing. Garter spring-type seals are used to retain the lubricant in the gearbox to prevent a leak into the power take-off clutch compartment or along the power take-off shaft.

The power take-off clutch, because of mounting on the high speed shaft, has a capacity when properly adjusted of better than twice that of the maximum operating engine torque. Adjustment of the clutch is by means of shims between the clutch back plate and the rear pressure plate. Shims are removed to tighten the clutch and this adjustment is readily accessible by removing the shield and cover assembly which is held in place by six capscrews.

The power take-off clutch is operated by a hand control level mounted to the left of the operator's seat. The lever is provided with a spring loaded latch to lock it in the disengaged position to prevent accidental engagement of the clutch.

Discussion by D. W. Innes

IT IS our experience that this subject is probably one of the livest subjects today in the farm machinery industry. Our experience has been mainly in the handling of windrowed material, and we have more or less grown up with the windrow method of harvesting. This experience has naturally brought us in close contact with the user of the small combine—the size which can be driven from the tractor power take-off.

The need for a continuous-running power take-off —sometimes referred to as the independent power take-off — has been obvious and is of greater importance than ever before since, in the threshing of windrowed grain, it is not possible to "cut out" to reduce the volume of material going into the combine, as is often done in the harvesting of standing grain.

The combine has to take the windrow as it comes — large volume or small. Our contact with this problem of handling properly the windrowed crop made a natural setting for us to consider the development of the unit we shall describe as "constant power."

The unit is designed for use with the John Deere tractor, since the design incorporated in these tractors lends itself to the design and construction of a relatively simple device to drive the power take-off shaft independently of the clutch used for traction.

The power source for our unit is the flywheel of the tractor which is conveniently located for our purpose. A sheave is attached to the flywheel and power is transmitted to a bevel gear case by means of a V belt.

The bevel gear case is secured by means of a rigidly constructed bracket attached to the rear axle housing. An over center, double-disk clutch with a conveniently located lever is incorporated in the unit ahead of the gears to allow for starting and stopping the implement being driven by the power take-off.

To the driven shaft, which extends through the rear wall of the gearbox in a position parallel to the conventional power take-off shaft, a sprocket is installed. A roller chain running from this sprocket to a second sprocket placed on the standard take-off shaft of the tractor completes the delivery of the power to the take-off shaft.

The constant-power attachment is engineered to handle the full power output of the tractor. The design is such that the speed of the power take-off shaft is the same as when driven in the conventional manner. It is obvious that the means normally used for engaging the power take-off shaft is left in the "out" position while the constant-power unit is installed on the tractor.

In addition to the essential parts of the unit which have already been described, the belt, clutch, and chain are safeguarded with adequate shields. To replace the usual shield over the power take-off shaft, a new shield is provided without destroying the standard connection for the detachable power shaft shields furnished with the various implements.

The experience we have had in actual operation of this unit falls naturally into two phases. The first phase is that

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experience derived through the operation of units which contained the essential principles of our present unit through several harvest seasons. This experience was very satisfactory to us and to the users. It was on this basis that we began the development and refinement of the present unit.

The second phase is that of operating a number of the units of the present design. Some of the users of the first units have also used the present ones and all are agreed that, with the refinements and features we have added, the unit is even more satisfactory and are enthusiastic about its possibilities. We have placed them in widely scattered areas in order to get a sampling of opinion.

It has been used with windrowing machines where it was pointed out to us that a great advantage is derived from the fact that, when the undergrowth is heavy and the grain is rank, it is possible to engage the tractor clutch without stopping the cutter bar, allowing the machine to clear itself without stopping and backing up. The same is true in operating a mowing machine in hay or weeds.

Its advantages can readily be seen in the operation of field choppers, spraying machines, front-end loaders — in fact, any implement which drives from the power take-off shaft while the tractor is traveling.

Coming back to the idea mentioned earlier, concerning the use of the combine in threshing windrowed grain, we know that the benefits of keeping the threshing mechanism up to speed are well recognized. Evidence of this is the fact that many, if not all, small combines have provisions for installing an auxiliary engine.

Even if the grain is not windrowed, but threshed from a standing position, the advantages of constant speed are not overlooked by the average user. The farmer is very conscious of loss of grain due to uneven threshing.

POWER OF TRACTOR ENGINE BELIEVED SUFFICIENT

The use of the auxiliary engine on the combine, the field cutter, the hay baler, and other power-driven machinery has been the answer to the problems arising from use of the conventional power take-off—situations where the power is turned off, momentarily at least, when the clutch of the tractor is disengaged, right at the time when the power is needed the most. It has been repeatedly brought to our attention that the power needed is already in the tractor engine—much more than is necessary for towing the implement through the field, the problem being of course to keep it flowing to the mechanism of the power-driven machine in an uninterrupted flow.

It is only necessary to mention the economies effected for the farmer if he can avail himself of a device which will, in one unit, serve, for practical purposes, the same as a separate auxiliary power unit on each of his several power-driven implements.

An important application which has added impetus to our efforts in the development of this unit has been the development of a baler, which, at the time we were in the early stages of our development, was known as the luebben baler. The unit has been used with this type of baler in several instances and the results have been most gratifying.

In operating this roll-type baler, it is required that the forward motion of the tractor be stopped after each bale is produced to prevent further intake of material while securing the twine to the bale. To accomplish this, the clutch is disengaged, transmission shifted into neutral position, clutch re-engaged in order for the power shaft to be operated to complete the bale. When the bale is ejected the clutch was again disengaged, the transmission shifted into forward gear, and the clutch re-engaged to resume forward travel. All this, as you can readily imagine, involves considerable work and causes the operator to expend a lot of his energy during a day's time, when upward of 1,000 bales are produced per day.

As an example of the increased production because of the actual labor saved, it was found in the case of using this constant-power attachment that one operator who had previously been producing 850 to 900 bales a day was able, with the use of this attachment, to increase his production to 1,400 to 1,500 bales a day with a tremendous amount of manual labor saved.

In making use of the constant-power unit it is not to be construed that the benefits in operating a power-driven implement are any greater than those derived when using an auxiliary engine, but rather that an economy can be effected when there is the need for this power on several implements. The power unit is readily available the moment the tractor is connected to any one of the several implements. These advantages will be appreciated especially when the implement has no provision for mounting an auxiliary engine.

We also realize that there are some tractors on the market that accomplish the same results that are accomplished by our constant-power unit, the provision for a continuous operating power take-off shaft being incorporated in their original design.

Probably other tractors will, in the future, have these same features. There are, however, a great number of tractors that will continue to be of service for several years whose users will be in need of and can use the attachment I have described.

Discussion by Elmer McCormick

THE use of the power take-off mechanism of a tractor to transmit power to the various moving parts of an agricultural implement or machine being propelled by the tractor does not extend very far back in history, its use being generally accepted by the farmer about twenty years ago. During the formative period just previous to its general adoption, various factors had their effect on the design that was adopted. The foremost of these was cost. Management felt that the farmer would not pay very much for this new gadget. As a consequence the engineer provided a design at minimum cost and number of parts.

When the design of the power take-off was still in the fluid or semi-congealed state, these same engineers recognized need for an independent drive from the power source. Such a design resulted in the McCray patent No. 1,957,221 filed November 23, 1928, and coming to issue May 1, 1934. To show you the thinking of those days, here is a portion of the preamble of the patent:

> "One of the principal objects of the invention is to provide an improved power take-off mechanism which is capable of transmitting power to the driven parts of the implement independently of the propulsion of the implement so that this power transmission can be made to occur while the implement and tractor are standing stationary. The desirability of this independent operation arises particularly in the case of implements having rapidly moving parts, or parts having heavy inertia, which must be brought up to speed before the implement can operate effectively. For example, in combines the thresher cylinder, blower fans, etc., must be brought up to speed before the implement has any operating efficiency. In prior take-off connections which are only operative to transmit power to the implement while the tractor is in motion, it is necessary after stopping the combine to back up the implement a considerable distance in order to allow the above-mentioned parts to be brought up to speed before the harvesting and threshing operation is again started. Moreover, in pulling a heavy implement up sloping ground, if it is necessary to stop the implement, it frequently develops that the tractor does not have sufficient power to start the operating parts of the implement and also to start the propulsion of the implement at the same time.
>
> "The present invention avoids these difficulties by enabling the power take-off drive to be thrown into operation before the tractor starts, thereby permitting the static friction of the operating parts of the implement to be overcome and these parts brought up to an effective speed before the implement is set into motion."

I have not made a study of the art as revealed by issued patents, but one patent cited by the examiner against the application of McCray was one issued to E. W. Burgess, April 29, 1919, and assigned to the International Harvester Co. This application for patent was filed September 22, 1915. While the two mechanisms have the same parts and general arrange-

ELMER MCCORMICK is chief engineer, John Deere Waterloo Tractor Works, Waterloo, Iowa.

ments, the drive on the Burgess mechanism originated in the transmission while the drive for the McCray mechanism originated from the crankshaft of the engine and therefore entirely independent of the transmission. It is interesting to note that power take-off drives were being thought of prior to the year 1915.

Our next attempt to provide independent power take-off drive was in 1931 when a new design tractor was built, tested, and later abandoned because of cost. You will recall that we were going into a depression at that time, and the farmer did not have the money to buy high-priced tractors and additional gadgets. I still consider the decision wise. At any rate the design proposed taking power off of an idler through two separate drives in which were two friction clutches, one for the main transmission and the other for the power take-off. Other attempts to provide independent power take-off drives were made. In fact, our new design department has had a continuing order on the subject, but the great obstacle has always been the cost.

The problem appears to be: (a) a study of the economics and (b) ability and/or willingness of the farmer to buy.

We have on the one hand the present power take-off, when sold as extra equipment, costs the farmer from $15.00 to $50.00. This price variation is dependent on the number and size of the parts furnished. Very rarely do these parts make the complete drive. Our cost analysis indicates that the cost of the present power take-off varies roughly from 2 to 4 per cent of the cost of a tractor.

At the other extremity the farmer may wish to buy a power unit for his combine or sprayer. This unit will probably cost him from $250.00 to $350.00 depending on the horsepower requirement.

Somewhere in between an independent clutch controlled power take-off drive can be fitted in if the costs and prices are not too great. When times return to normal, the question is what will the farmer be willing to pay. From present knowledge it appears the cost will be roughly two and one-half times the present cost of power take-off drives.

ADVANTAGES OF INDEPENDENT POWER TAKE-OFF

Here is what the independent power take-off will do for a farmer that his present power take-off won't do:

1 It provides for putting in motion the revolving parts of the implement before starting the forward travel of the machine.

2 It provides stopping the forward travel. Some operators may slip the clutch to retard the forward travel, but this practice should be discouraged. It leads to overheating and wear in clutch parts.

3 It decreases delay due to gear shifting to operate the power take-off to clean a plugged or partially plugged machine and makes it unnecessary to back up to get a fresh start.

As I see it, some machines require the tractor engines to be operated at full throttle at all times. Such machines are combines and sprayers. Such being the case the rate of forward travel is determined by the fixed gear ratios of the various speeds. More speeds in smaller increments may be one of the answers to the problem. On the other hand, the use of an independent power unit on the combine or sprayer makes it possible to maintain the proper rotative speed on the implement and vary the rate of forward travel of the tractor and implement by throttling the speed of the tractor engine and/or changing gears. Flexibility is obtained with an engine-driven implement over an independent-driven power take-off equal to the infinitely variable V-belt drive of some self-propelled combines.

From this we can conclude that

1 The independent power take-off cannot be expected to equal the performance of an engine drive

2 It is better than the present power take-off hitched to the transmission gear

3 It will cost the farmer more money which should offer no sales resistance during present economic conditions.

"Direct Engine-Driven Power Take-Off"

TO THE EDITOR:

THE paper on power take-off drives by Frank Kranick published elsewhere in this issue prompts the following comments:

Since necessity usually is the mother of invention, quite a number of engineers early realized the need or desirability of a direct power take-off drive particularly in connection with combines. Some of the earlier attempts with such drives involved supplying power to combines of somewhat larger size than what we know today as the more or less conventional power take-off-driven machines, and under such circumstances the desirability of such a direct drive was soon apparent. It was also apparent there existed a decided lack of balance between the size of the combine and the power available from the tractor engine, which condition was somewhat later modified with the advent of the smaller-size power take-off driven machines.

The great increase of the smaller-size tractors for general farm use is, however, again reacting to unbalance the combine-tractor combination, with the result that we are going back to about where we began, so far as always having what might be considered as the necessary amount of power to run a combine is concerned. Also, we have the condition where a tractor might not always be in good working order, even though it might appear to be large enough for the job; and here again we meet the same unbalanced conditions already mentioned.

Since the successful operation of a power take-off combine very often requires its maximum share of power available from the tractor engine, it is easy to realize that under some crop conditions the lowest gear on practically all current tractors is still altogether too fast a ground speed to meet certain extreme crop variations, without choking down the combine or providing the means for keeping it up to its proper working speed. Choke-ups in the combine are not only very annoying to the operators but also involve considerable loss of time. Likewise any serious variation in the speed of the combine operating mechanisms is also conducive to grain wastage as well as to poor over-all machine performance.

These are the conditions then wherein it would appear that a direct drive for the power take-off would be desirable so that the tractor transmission clutch could then be disengaged in order to permit a slow enough forward tractor ground speed to suit the capacity of a combine. This sounds good so far, but how about the tractor transmission clutch? Is it in turn constructed in a manner to successfully stand intermittent slipping in order to drop the forward speed considerably below the lowest transmission gear speed provided on the tractor? I doubt very much if the conventional type of tractor friction clutch will stand up under such conditions.

Harvesting conditions in any one field could easily vary to the extent that it might be intermittently necessary to reduce the forward ground speed considerably for quite some distance in order to stay below or match the capacity of the combine, or other types of power take-off driven machines, and therefore, if under such conditions it becomes necessary to resort to tractor transmission clutch slippage in order to accomplish the desired results, the benefits then of a direct engine-driven power take-off shaft might easily be off-set by considerable clutch trouble. So far as conventional tractors are concerned, it could be said that possibly one added low gear would answer in most cases for the reasons already mentioned. Or, if we were to further consider the direct power take-off drive in combination with the present tractor ground speeds, the proper type of tractor transmission clutch would surely have to be provided to meet the conditions as already explained.

Another approach would be that since some gearing would be involved, even for a direct-driven power take-off shaft, it might be more practical to provide a gear speed change directly associated with the power take-off line in the tractor so that it would then be possible to throttle the tractor engine down in speed to a point inside of its high torque range and still deliver the required rpm to the power take-off shaft, and in that way considerably reduce the ground speed of the tractor without the necessity of slipping the tractor transmission clutch.

In the operation of corn harvesting machines, it has often been found that a change in speed of the operating mechanisms would be desirable in order to meet certain crop or field conditions as against the present combination of fixed power take-off speeds in relation to the present conventional fixed tractor ground speeds.

Another point that also deserves consideration comes about in the condition where we could have a tractor of ample or greater power as might be required to satisfactorily run a combine.

Under such conditions where a rather large-size tractor is used in combination with some of the smaller size combines, we find that, even though we might have ample power available to run the combine, the crop conditions might be such that, with the present low gear tractor ground speed, it would still be possible to greatly exceed the capacity of the combine. Under these conditions, then, the machine performance could not be satisfactory, and, worse yet, the excess of power available from the tractor would be conducive to tearing up such power take-off-driven machines because of overcrowding, (*Continued on page 250*)

The Standard Power Take-Off—Is It Good or Bad?

By E. W. Tanquary
MEMBER A.S.A.E.

ONE approach to the question of whether the present power take-off speed is good or bad would be to consider a new speed more in line with the engine speed of present-day tractors and more adaptable to the operating speed of power-driven implements. Exploring this line of thought a little farther, we might ask what power take-off would we, as farm implement engineers, recommend that would enable us to design power-operated implements that are better from an engineering or functional standpoint, or to simplify the construction to provide a less costly piece of equipment.

Before examining the operating speed of various implements, it is apparent the operating speed of combine sickles or corn picker gathering chains must be based on the ground speed of the implement operating under average conditions. Picker rolls and other units on the same implement, while operating at a different speed, are also coordinated with the rate of travel. Speed changes to compensate for different crops or field conditions are required for thresher cylinders and similar units. Therefore, no matter what speed may be adopted for the power shaft, it can be determined that no one speed can be used to operate the various units on any power-driven implement.

Immediately after the implement power line is connected to the tractor power take-off shaft, the drive is transmitted to a gearbox or supplemental transmission on the implement or by means of V belts and sheaves to increase or decrease the speed to suit the requirement of the particular implement. It would seem that a speed could be determined that would be suitable for a group of implements and permit elimination of the speed change. However, if we examine the operating speed of the output shaft or main countershaft on a number of our more popular power-driven implements, the following range will be noted:

Grain binder	540 rpm
Tractor binder	543
Windrower	540
No. 52 - No. 62 harvester-threshers	815
No. 24-P corn picker	825
No. 14-P - No. 2-P corn pickers	510
No. 1-P corn picker	540
Power-drive manure spreader	225
Ensilage harvester	1500
Corn binders	599
Field hay chopper	987
Mowers	900 - 1000

From these figures we might theoretically determine that a speed of 825 rpm would permit a direct drive to our harvester-threshers and corn pickers of more recent design. The same speed would permit a better V-belt application for mowers. However, as we examine implements such as the harvester-threshers, corn pickers and ensilage harvesters, we find gearboxes would still be required to transfer the power from the power line through a right-angle drive to operate those units running parallel to the line of travel. Transmissions would still be required on machines, such as potato diggers, where it is necessary to vary the apron speed to suit field conditions.

On our No. 52 harvester-thresher, operating with a countershaft speed of 825 rpm, a 26-T bevel gear with a 17-T pinion are employed. Increasing the power take-off speed to 825 rpm to provide a 1-to-1 ratio would permit only a slight reduction in the size of the gearbox.

On engine-drive machines speed reduction would still be necessary, and on some applications a right-angle drive is required.

While a power shaft operating at the 825 rpm selected for this discussion as the most promising would, from the implement standpoint, theoretically permit use of a power shaft smaller in diameter, we know the centrifugal force would increase by the square of the increase in speed. Thus an increase in speed of 50 per cent on the long power shaft required on corn pickers and combine threshers would increase the centrifugal force four times. This factor must be considered with our present construction utilizing a floating bearing at the front of the A frame and no other anchorage between the front bearing and the gearbox at the rear of the implement.

While we have no definite data to present, we have conducted numerous tests on our harvester-threshers and corn pickers with various types of power lines and the experience gained definitely indicates this long power shaft, which, on implements such as our ensilage harvester, in difficult cutting transmits up to 30 to 33 hp, would require both static and dynamic balancing—a troublesome and costly operation.

Summarizing, it appears there is little to be gained so far as implement design is concerned either from a functional or economical standpoint. You may not agree with the 825 rpm speed selected as a basis for discussion in this paper as the operating speeds will vary with different makes of equipment, but the analysis of the problem should apply generally to other makes of equipment.

The last and perhaps the most important phase of the problem is the interchangeability of implements and tractors. Because of the relationship of operating speed to ground travel, any change in the power take-off speed exceeding 10 to 15 per cent would require conversion packages for both tractors and implements.

Where old implements built to operate at 536 rpm would be used with a new tractor equipped with a higher speed power take-off, a tractor conversion package consisting of a speed reducer would be required. In addition to the burden imposed on the manufacturer and dealers in furnishing these conversion packages, the farmer would be burdened with installation of the conversion for operating old implements and

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This paper was presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1947, as a contribution of the Power and Machinery Division.

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EDITOR'S NOTE: The program of the 1947 A.S.A.E. Winter Meeting included a panel discussion of the subject "The Standard Power Take-Off Speed — Is It Good or Bad?" The accompanying contribution to that discussion, by Mr. Tanquary, it is believed, faithfully reflects the thinking and conclusions of the other engineers who participated in the same discussion.

In providing us with a transcript of his remarks, Mr. Tanquary makes some further comments which perhaps represent the attitude of most engineers toward the question of the present standard power take-off speed. They are so pertinent to the discussion that they are included here, as follows:

"After listening to the panel discussion, it may have seemed to those present as though the panel speakers had met some place and decided to 'kill the bug' before it got too big to handle. However, this was not the case, and so far as I know there was no getting together to 'compare notes' on the subject prior to the time our discussions were given at the meeting.

"Frankly, I have always been in favor of a higher power take-off speed, since it introduces possibilities for V-belt drives. Before exploring the subject very far, a higher speed seemed to offer possibilities for gear reduction, and I thought at the time a lighter and more economical construction.

"Therefore, when the subject came up, I was greatly interested in the problem and originally set out, as mentioned in my paper, to determine a speed that would permit accomplishing some of the things I had visualized. Theoretically, some good answers could be given, but practically I find very little mechanical advantage, and finally it seemed disadvantageous as it would involve considerable expense to all tractor and implement manufacturers, as well as to our customers. The disadvantages would thus more than offset the minor advantages that might be gained.

"These comments are made mainly because the discussion may have seemed to be rather one-sided, and also because the question was raised as to why the subject was even included on the program since everyone was so much against it. I feel that it was a very worth-while exploration, and that it should serve to set at rest any notion about changing the present standard power take-off speed."

removal of the conversion for operating new implements. Certain problems would be encountered in providing adequate power-line shielding where these conversion packages would be required.

Should the farmer purchase a new implement for use with his old tractor, provision would have to be made to compensate for the slower power take-off speed. This would mean manufacturers and dealers would have to carry two sets of gearboxes or transmissions for each type of implement in order to take care of his customers who might have either an old or a new tractor. Where the farmer has more than one tractor, the problem is even more complicated.

Standardization of the power take-off shaft, master shield, and drawbar hitch point created similar problems in interchangeability of tractors and implements, but the advantages gained by a safer hookup and the ultimate saving to the farmer justified the complications encountered during the transition period. A change in the power take-off speed would be of little benefit to the farmer, certainly not enough would be gained to justify the problems that would be encountered.

It is therefore my recommendation that the present 536 rpm power take-off speed be retained.

Irrigation Research in Georgia

(*Continued from page 244*)

pipes above the portable laterals. Early installations were usually of the fixed pipe type, but the demand for these is lessening.

For the research studies with supplemental irrigation of pastures, vegetables, and field crops at the University of Georgia, a 15-acre site was selected adjacent to a river on the University farm. The soil is Congaree fine sandy loam, which is a first bottom soil in the Piedmont. Most of the site was fairly level, but a few plots were located on the footslope of the adjacent hill land where the slope was about 5 per cent.

A 2-in centrifugal pump driven by a 17-hp air-cooled gasoline engine, both mounted on a surplus war bomb trailer, was used for pumping water. An underground supply main delivered the water to the plot sites. Portable metal pipe with quick-coupling joints and rotating sprinklers completed the system. The pumping outfit is shown in Fig. 2 and the pipe and sprinklers in Fig. 3.

Sprinklers were placed every 40 ft in the line, with the lines approximately 60 ft apart. A fairly good distribution of water was obtained under these conditions when operated at 40 psi. Distribution tests from a single nozzle and the resultant pattern between four nozzles are shown in Figs. 4 and 5, respectively. The quantity of water diminished with distance from each nozzle. Wind velocity, even as low as 2 to 3 mph, caused some distortion to the distribution pattern. The maximum diameter of throw was approximately 120 ft from the single nozzle operating at 40 psi. Observations indicated all the soil was wetted thoroughly even though there was considerable variation in the measured distribution between the four nozzles illustrated in Fig. 5. Results of other tests checked closely with the manufacturer's published discharge tables for the respective nozzles and pressures used.

The research results obtained in 1946 and 1947 will be given in Part II of this paper, to be published in AGRICULTURAL ENGINEERING for July.

BIBLIOGRAPHY

Dumm, Lee D., and Liddell, W. J. Preliminary Climatological Study of Relationship Between Amount of Rainfall and Drought Occurrences in Georgia. Annual Report, Research and Investigational Activities, College of Agriculture, the University of Georgia, June, 1946.

Herrick, S. M. Ground Water for Irrigation in Georgia. AGRICULTURAL ENGINEERING, November, 1946.

Thomson, M. T. Application of Stream Gaging to the Agricultural Use of Small Streams and Ponds. AGRICULTURAL ENGINEERING, December, 1946.

Warren, M. A. Artesian Water in Southeastern Georgia, Bulletin 49, Georgia Department of Mines, Mining, and Geology, 1944.

(To be concluded in the July issue)

Artificial Shades for Livestock in Hot Climates

(*Continued from page 242*)

The investigations at Meloland Field Station will be continued in the summer of 1948. A larger number of cattle will be available for the tests and more shades are being constructed. The effect of shade size and height, louvres in the roof, cooling of walls and roof by evaporation, and evaporative cooling of air will be studied. The subject of ground radiation will be given more attention. A model weather station will be installed and the records obtained will allow for a correlation between the weather and the environment as modified by the shades. The effect of radiation and air temperature on the surface temperature of the animals will be determined in greater detail.

SUMMARY

These first-year tests show that there is a slight difference in the reaction of Hereford heifers kept under shades with roofs of different materials. The effect of shades on heat exchange by radiation and convection is pointed out. Ground temperatures in the sun at midday varied from 124 to 148 F, at an air temperature of only 89 F, depending on the ground texture and density. Animal surface temperatures ranging from 104 F in the shade to 130 F in the sun were observed. Wetting cattle gives them some degree of comfort, but the use of water in this way adds a definite sanitation problem. By using suitable shades and feedlot surfaces, and water as a cooling agent, there is some hope of correcting the reactions of cattle to high temperatures. The end result would be increased production and greater gains during the summer months.

REFERENCES

1 Brody, Samuel. Bioenergetics and Growth, page 98, Reinhold Publishing Company, 1945.

2 Kleiber, Max and Regan, W. M., and Mead, S. W., Measuring Food Value for Dairy Cows. Hilgardia, May 1945, vol. 16, no. 11.

3 Reinerschmid, G., The Amount of Solar Radiation and Its Absorption on the Hairy Coat of Cattle Under South African and European Conditions. Journal South African Medical Assn., 14, no. 4, pages 121-141, 1943.

4 Hardy, James D., The Radiation of Heat From the Human Body — Part 1, An Instrument for Measuring the Radiation and Surface Temperature of the Skin. Journal of Clinical Investigation, vol. 13, 1934, p. 593.

5 Brown, A. I. and Marco, S. M., Introduction to Heat Transfer, p. 52. McGraw-Hill Book Co., Inc.

6 Brody, Samuel, Bioenergetics and Growth, p. 359.

Direct Engine-Driven Power Take-off

(*Continued from page 248*)

which condition again would not be corrected unless a slower forward ground speed of the tractor was available.

Some of the references in this discussion would also apply to the further discussion in this same meeting concerning the issue of proper speeds for the power take-off shaft. As I see it, the standard speed for the present type of power take-off shaft appears to be about as good as could be selected for that type of drive, but, on the other hand, the problems associated with the development of the direct engine-driven type might call for some modification, in view of some of the circumstances before mentioned. If it were considered advisable to provide some range of speed for the power take-off drive, this would be the time to consider such an issue rather than to have to do the job all over again at some later date.

All in all, it would appear that the application of a direct engine-driven power take-off represents a trifle more engineering than just placing a shaft in some other selected driving position, but rather careful consideration of a number of other factors as well. The proper type of power take-off drive incorporated in the tractor would not only increase the usefulness of such machines, but it would also eliminate the necessity of burdening the farmer with the added expense of supplemental power units for a variety of machines in general use. Our service to the farmer would be in reducing his overhead expense and investment and at the same time provide him with the most efficient type of tools to do the job, and not, as in some cases, load him up with the expense of extra engines which might be idle 90 per cent of the time.

Research Engineer
J. I. Case Company
N. R. KRAUSE

Supplemental Heat in Mow Drying of Hay — Part II

By Roy B. Davis, Jr. and Gordon E. Barlow, Jr.
Junior Member A.S.A.E. Junior Member A.S.A.E.

AN ANALYSIS of the factors affecting the use of supplemental heat in barn drying forage crops has been an objective of forage-drying research for a number of years. The investigators assigned to the cooperative forage drying research project in the Farm Electrification Division (BPISAE), U. S. Department of Agriculture, and the Virginia Agricultural Experiment Station began a study of these factors in 1946. This study was continued and expanded during 1947. Results of the 1946 studies have been previously presented[1*]. The following discussion is a progress report which gives the results of the 1947 studies, and where possible combines the results of both years.

Among the factors studied were the effect of temperature and relative humidity on drying rate, the effect of initial moisture content on the rate of drying, moisture removal from the various layers of hay in the mow, heat generated in the forage, and the change in the chemical composition of the hay that took place in the hay during drying as affected by condition of the entering air, initial moisture content, and position in the mow. This paper deals with the first four of these factors. The change in chemical composition during drying will be presented later, after observations have been more thoroughly analyzed and the statistical significance of differences in chemical composition determined.

This paper was prepared expressly for AGRICULTURAL ENGINEERING.

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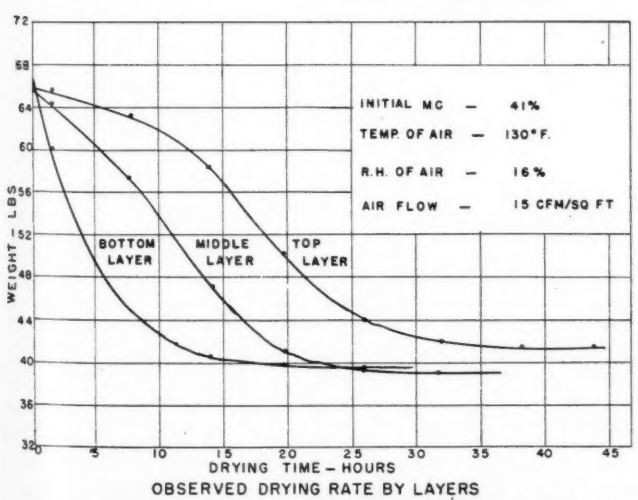
Experimental Equipment and Procedure. The laboratory equipment used for this study was expanded in 1947 by the construction of four additional bins. The bins used in 1946[1] were used again in 1947. These bins are located outside the laboratory and will be referred to as the large bins.

The new bins were smaller and of somewhat different construction. They were located inside the laboratory and will be referred to as the small bins. Each bin was made up of three drying sections arranged vertically, as shown in Fig. 1. Each section was 2 ft square and had a maximum storage depth of 2½ ft. The bottom and middle sections were adjustable in depth by means of telescoping sidewalls. Each section had a mesh wire bottom and the joint between the sections was made airtight by means of a sponge rubber gasket. This equipment made possible the study of drying rate of each of the three layers in the column. The hay in the bottom and middle sections made contact with that in the section above it, for as the hay settled the sidewalls of the sections telescoped and the height of the section was reduced by the amount of the settling. This was done to simulate as nearly as possible the conditions found in the mow.

When these sections were filled with hay and arranged for the drying test, they were placed over a plenum chamber. Air under pressure was delivered to the four plenum chambers by a blower driven by an electric motor. The amount of air going to each plenum chamber was controlled by a gate in the air supply duct. The air passing through the hay was collected

Fig. 1 A view of the laboratory installation in which the hay was dried in small bins. The steam heating units are shown in the extreme right foreground. The air duct extending from the left of these units housed the fan. The drying columns are shown beyond this duct. (Virginia Agricultural Experiment Station photo)

*Superscript numbers refer to appended references.



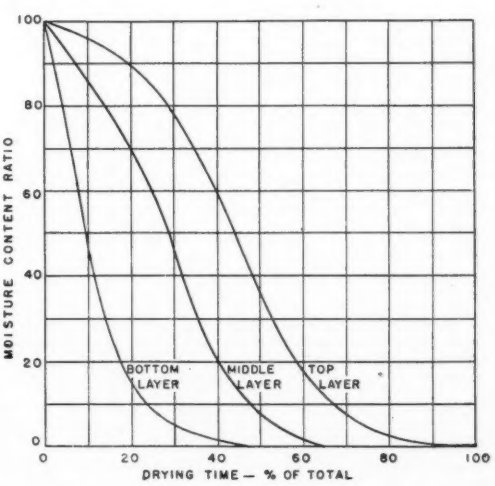


Fig. 2 (*Left*) The observed relation of the loss of weight and drying time in one of the 32 bins dried in this series. This relationship is shown for each of the three layers of hay in the bin • Fig. 3 (*Right*) This graph shows the observed drying rate data of Fig. 2 on the basis of the percentage of total. Change in weight is shown as moisture content ratio and is the percentage of moisture yet to be removed. Drying time is shown as the percentage of time required for the top layer to reach a constant weight

in a plenum chamber in the top section of the column and discharged through an orifice, which was used to measure the amount of air passing through the hay. Steam radiators and electric heaters were used to heat the air entering the hay to the desired temperatures.

During 1947 a series of eight drying tests was made in the small bins. For each test, the twelve drying sections were each filled with equal weights of chopped alfalfa hay. Moisture content of the hay was very nearly constant for any one test but varied from 40 to 70 per cent (wet basis) in the series of tests.

Each of the four columns of three sections was dried with air of a different temperature entering the bottom of the column. The temperatures used throughout the series of tests were 100, 110, 120, and 130 F. During the drying tests, the temperature and humidity of the air entering and leaving the columns and the loss of weight in each section were recorded. The temperatures and humidities at each of the above points were recorded continuously and the loss of weight observed at regular intervals. Weighing each section was accomplished by raising the middle and top sections and weighing the bottom section; the middle section was lowered and the weight of the bottom and middle was determined; finally the entire column was weighed. The weight of hay in each section was determined by subtraction.

The range of conditions under which these data were obtained is summarized as follows:

Initial moisture content (wet basis)	40 - 70 per cent
Temperature of entering air	100 - 130 F
Humidity of entering air	13 - 40 per cent
Depth of hay	5 - 8 ft
Type of material	Alfalfa - alfalfa heavy grass mixed
Time of cutting	Prebloom - Full bloom
Air flow	15 cfm/sq ft

In addition to the drying tests run in the small bins, four tests were run in the large bins. Supplemental heat was used in each of these tests. An entering air temperature of 80 F was used in one bin and 90 and 100 F for the other two tests. The tests run in the outside bins are summarized in the following table:

Test	Initial depth	Initial moisture content	Bin A Temp.	Bin A R.H.	Bin B Temp.	Bin B R.H.
1-47	9 ft 0 in	63.5	80	50	90	38
2-47	8 ft 4 in	56.9	90	35	100	27
3-47	10 ft 2 in	55.8	90	53	100	40
4-47	8 ft 0 in	66.8	80	48	90	36

LAYER DRYING OBSERVED

Observers interested in forage drying have reported on several occasions the theory that the forage dries in layers or zones. They report that drying starts and is initially most rapid at the point the air enters the forage, and, as drying continues, this zone of drying moves through the hay in the direction of air flow until the entire mass is dry. This was observed very conclusively in the tests using the small bins. The weight of each section was plotted against drying time. A set of curves showing the weight of each of the three layers in a single bin is shown in Fig. 2. A similar set of curves was plotted for each test. Each seemed to follow the same pattern regardless of the depth, initial moisture content, or condition of the entering air. This does not mean that these factors do not affect drying, but it does mean that, when these data from the various drying runs are expressed on a common basis, that is, percentage of total, they follow the same form. It will be noted from Fig. 2 that drying was continued until each of the layers reached a weight where no further loss was observed. This weight was assumed to be the equilibrium[2] weight and the difference between this weight and the initial weight was the total change in weight.

The zone drying is illustrated by the rapid loss of weight in the bottom layer at the beginning of drying, and as this layer neared its equilibrium weight the drying in the middle layer became most rapid. This is repeated in the top layer with respect to the middle layer.

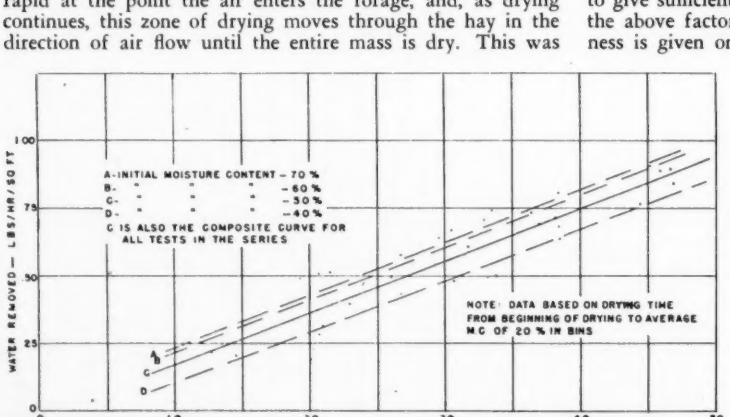
Fig. 3 shows these drying curves plotted on the basis of the percentage of total. The time required for the top layer to reach a constant weight is taken as total drying time. The ordinate of this set of curves "moisture content ratio" shows the weight yet to be removed at any time. This ratio is computed by the following formula:

$$\text{Moisture content ratio} = \frac{\text{weight at time } X - \text{equilibrium weight}}{\text{initial weight} - \text{equilibrium weight}}$$

$$\text{or M.C.R.} = \frac{\text{M.C. (dry basis) at time } X - \text{equilibrium M.C. (d.b.)}}{\text{initial M.C. (d.b.)} - \text{equilibrium M.C. (d.b.)}}$$

For example, a layer of hay with an initial moisture content of 80 per cent (dry basis) is dried by passing air of a given temperature and humidity through it. The condition of the air is such that the hay will dry to an equilibrium moisture content of 10 per cent (dry basis). When the layer has reached a moisture content of 50 per cent (dry basis), it will have a "moisture content ratio" of $(50-10)/(80-10)=0.57$, or 57 per cent.

During the runs, the air leaving the hay had a constant relative humidity at or slightly below saturation for approximately 36 per cent of the total drying time. It may be noted from Fig. 3 that, after 36 per cent of the total drying has elapsed, the bottom layer has practically reached equilibrium and the middle layer has lost 80 per cent of the total weight to be lost. Thus we might conclude that the air passing through the hay reached its maximum relative humidity when passing through a hay thickness equal to the thickness of the top layer and a small portion of the middle, or approximately 3 ft. This thickness probably depends on a number of factors, such as velocity, temperature, and humidity of the air, and the moisture content of the hay. The observations taken failed to give sufficient information to evaluate the effect of each of the above factors; therefore, the average value of this thickness is given only as a guide.


WATER REMOVED — LBS/HR/SQ FT
A-INITIAL MOISTURE CONTENT – 70 %
B- " " " – 60 %
C- " " " – 50 %
D- " " " – 40 %
C IS ALSO THE COMPOSITE CURVE FOR ALL TESTS IN THE SERIES
NOTE: DATA BASED ON DRYING TIME FROM BEGINNING OF DRYING TO AVERAGE M.C. OF 20 % IN BINS
DIFFERENCE BETWEEN DRY BULB AND WET BULB TEMPERATURE OF ENTERING AIR — ΔT °F.

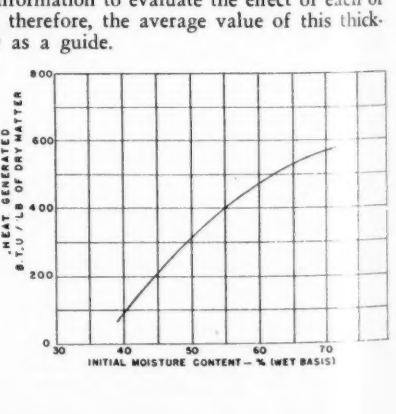


Fig. 4 (*Left*) The relationship of the difference between the dry-bulb and wet-bulb temperature of the entering air and water removed observed in this series • Fig. 5 (*Right*) The relationship between the heat generated in the hay and the initial or storage moisture content

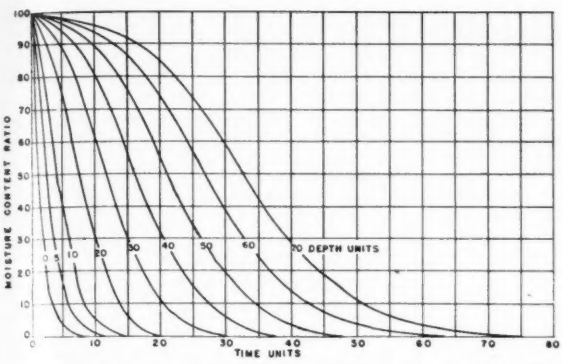


Fig. 6 The relation of drying time, hay moisture, and hay depth. This graph was obtained by combining the observed relation of these factors from each of the 32 drying tests

This brings up the question of why the top layer started losing weight at the beginning of the test and continued at a fairly constant rate for approximately 25 per cent of the drying time. If the air reaches its maximum relative humidity in 3 ft of hay, then at the beginning of the test the air passing through the top layer should not have removed moisture from the top layer. It is believed that heat generated in the hay[3,4] is responsible for this drying. The amount of this heat is appreciable and will be treated in more detail later in this discussion.

Effect of Temperature and Humidity on Drying Rate. In the drying tests conducted in 1947, air temperatures of 80 to 130 F, (at intervals of 10 F) were used. In analyzing the effect of these temperatures on drying rate, the difference between the wet and dry-bulb temperature was used as the basis for consideration. This temperature difference expresses the relationship between temperature and humidity, and thus simplified the analysis. Initial moisture content was found to be a factor in explaining differences in drying rates with a given air condition. The results of this analysis of drying rates is shown in Fig. 4. The abscissa of this graph is the difference between the wet and dry-bulb temperature of the entering air. The ordinate is the weight lost per hour per square foot of bin area. This rate of weight loss was based on the weight lost from the beginning of the test until the hay in the bins had reached an average moisture content of 20 per cent (wet basis). Curves are shown for initial moisture contents of 40, 50, 60, and 70 per cent. The curve of best fit for all of these observations irrespective of initial moisture content, as determined by the least squares method, is weight loss per hour per square foot $= -0.02+0.0192\Delta T$, with a correlation coefficient of 0.90. This curve is approximately that for an initial moisture content of 50 per cent. These observations indicate that for 40 per cent hay the Y intercept should be decreased to approximately -0.08, and for 60 per cent and 70 per cent should be increased to $+0.02$ and $+0.04$, respectively.

Heat Generated in the Hay. Throughout this discussion the amount of heat generated in the hay has been mentioned as being the cause of variations in several of the relationships. The observations taken on the small drying bins were examined to determine whether the amount of this heat could be determined. Since during the early stages of drying the air leaving the bins had a constant humidity at or slightly below saturation, it was assumed that all the available heat in the entering air was used to evaporate water.

The amount of total heat supplied and the observed moisture loss during this initial period was used to compute the portion of heat required to evaporate a pound of water supplied by the entering air. The difference between this value and the latent heat of drying was used to determine the amount of heat supplied by the hay. The latent heat of drying was assumed to be that of free water and determined from steam tables to have a value of about 1100 Btu per lb of water evaporated. On this basis the amount of heat supplied by the hay has been computed and is expressed in terms of heat generated per pound of dry matter in the bins. The heat generated per pound of dry matter has been determined for each of the small bins and is shown graphically in Fig. 5 with initial moisture content of the hay as the abscissa of the curve.

This method of computation gives only an approximation of the heat generated since the amount generated after the relative humidity started to fall has been neglected. This could not be included because the loss of efficiency of drying would also be a factor in these latter stages of drying. Therefore, it is felt that, while the values shown are somewhat conservative, they are a good indication of the amount of heat supplied by the hay.

Generalization of Observations. This analysis of drying rates was carried further by combining the curves of the various tests into a general set of curves for the series. The method of analysis is that used by Hukill in analyzing the drying rates of corn and grain sorghum[5]. The result of this analysis is shown in Fig. 6. The ordinate of this chart shows the change in moisture content during drying as is expressed in terms of the "moisture content ratio". This term has been previously defined. Drying time is shown as the abscissa and is expressed in terms of "time units". A time unit is defined as the time in hours required for fully exposed hay to dry halfway to its equilibrium. This time is dependent on the temperature and humidity of the drying air. For air with a 68 F dew point, a time unit was determined experimentally to have the following values:

Dry bulb temperature, F	Time unit, hrs
90	6.5
100	4.2
110	2.6
120	1.6
130	1.0

Raising the dew point for a given dry bulb temperature was found to increase the length of time in a time unit.

The various curves on this chart show the drying rate for various depths of hay in the column. These depths are expressed as "depth units". A depth unit is defined as containing enough hay that, if all the theoretically available heat could be used, it would dry to equilibrium in the time taken to dry fully exposed hay halfway to equilibrium. From this definition the number of pounds of hay contained in one depth unit is

$$G = \frac{Q \times 60 \times \Delta T \times Sa \times H}{.01 \times \Delta M \times V}$$

where G is the pounds of dry matter in a layer of hay one unit deep

Q is the volume of air in pounds per minute

ΔT is the maximum temperature drop that may occur in the air, or is the difference between the wet and dry-bulb temperature of the entering air

Sa is the specific heat of air

H is the time in hours required by fully exposed hay to reach halfway to its equilibrium moisture

ΔM is the initial moisture minus equilibrium moisture (per cent dry basis)

V is the latent heat of drying, assumed to be 1100 Btu per lb.

Using this formula, the number of pounds of hay required to make a depth unit was computed for each of the layers of hay dried in the small bins. From this the number of depth units contained in each layer was computed. The drying curve for each layer was then plotted with "moisture content ratio" as the ordinate and time unit as the abscissa. They were then combined into the form as shown in Fig. 6.

The following example is given to illustrate the use of the chart (Fig. 6). Alfalfa hay with a moisture content of 100 per cent (dry basis) is to be dried on a mow hay drier. The air to be blown through the hay will have a dry-bulb temperature of 90 F and a relative humidity of 45 per cent and will be blown through the hay at the rate of 15 cfm per sq ft of mow area. Drying will be complete when the moisture content in the top layer reaches 20 per cent (dry basis). How much hay can be dried under these conditions in four days?

First, compute the moisture content ratio desired in the top layer. Dexter, Sheldon, and Waldron[2] report that air with 45 per cent relative humidity will dry hay to an equilibrium of approximately 11 per cent (dry basis). Then the moisture content ratio in the layer will be 20 − 11/100 − 11 =0.10 or 10 per cent.

The conditions stated above give the value of the constants to be used in determining the number of pounds of dry hay in a depth unit. The values are:

$$Q = 15 \div 14.1 = 1.06 \text{ lb per sq ft per min}$$
$$\Delta T = 90 - 73.0 = 17 \text{ F}$$
$$Sa = 0.24$$
$$H \text{ at } 90 \text{ F, } 68 \text{ deg dew point} = 6.5 \text{ hr}$$
$$\Delta M = 100 - 11 = 89 \text{ per cent}$$
$$V = 1100 \text{ Btu/lb}$$

By substituting in the equation above,

$$G = \frac{1.06 \times 60 \times 17 \times 0.24 \times 6.5}{0.01 \times 89 \times 1100} = 1.72 \text{ lb of dry hay per depth unit per square foot of mow area.}$$

Next determine the number of time units in four days when a time unit is 6.5 hr:

$$4 \times 24 \div 6.5 = 14.7 \text{ time units}$$

From Fig. 6 it may be noted that hay 21 depth units deep will dry to moisture content ratio of 10 in 14.7 time units. Twenty-one depth units would contain 1.72 x 21 = 36 lb of dry hay per square foot of mow area. The total amount of hay that could be dried in a given mow under the given conditions would then be 36 times the area of the mow in square feet.

While this chart is generalized to a certain extent, it is believed advisable to remember that the data were determined experimentally and represent a range of conditions. The range of conditions covered by these observations are rather wide in some respects and limited in others.

SUMMARY

The maximum rate of drying was observed to take place initially at the entrance of the drying air. This zone of drying moved through the column of forage toward the air exhaust as the drying progressed. The drying air reached its maximum relative humidity while passing through about 3 ft of forage.

Corresponding layers appeared to follow the same pattern regardless of initial moisture content or condition of entering air. This indicates that forage-drying rates may be generalized when proper constants are applied for varying conditions.

Heat generated in partially cured forage is appreciable and perhaps accounts for the drying observed in upper layers of hay even though the air entering these layers has reached a high relative humidity. The rate of heating increased as initial moisture content was increased. It was noted that the heat generated per pound of dry matter increased rather rapidly as initial moisture content was increased to 45 to 50 per cent. Above 50 per cent it continued to increase, but less rapidly.

Within the range of wet and dry-bulb temperatures used in this series of observations, it was found that rate of moisture removal was proportional to the difference between these criteria of air condition. This observation is based on data obtained when the dry-bulb temperature of the entering air was thermostatically controlled and not subject to ambient temperature variations. The rate of moisture removal in pounds per hour per square foot of bin area was higher for higher initial moisture contents. This is due to the higher rate of heat generation at higher moisture contents which speeds the rate of moisture removal.

Although the data were obtained from a rather wide range of conditions, it was necessary to make several assumptions which may require modification. It is hoped that further investigation will show the extent of the changes necessary to make these data more generally applicable.

AUTHORS' ACKNOWLEDGMENT — The authors are indebted to Dr. M. H. McVickar, agronomist, Prof. C. W. Holdaway, dairy husbandman, and Dr. R. E. Mather, associate dairy husbandman, of the Virginia Agricultural Experiment Station for their advice and assistance in conducting this work.

REFERENCES

1 Davis, Roy B., Jr., Supplemental Heat in Mow Drying of Hay, AGRICULTURAL ENGINEERING, vol. 28, no. 7, July, 1947.

2 Dexter, S. T., Sheldon, W. H., and Waldron, D. I., Equilibrium Moisture Content of Alfalfa Hay, AGRICULTURAL ENGINEERING, vol. 28, no. 7, July, 1947.

3 Hendrix, A. T., Heat Generated in Chopped Hay and Its Relation to the Drying Effect, AGRICULTURAL ENGINEERING, vol. 28, no. 7, July, 1947.

4 Hendrix, A. T. and Zerfoss, G. E., Dry Hay by Forced Circulation of Air, Special Report No. 34, TVA, October, 1947.

5 Hukill, W. V., Basic Principles in Drying Corn and Grain Sorghum, AGRICULTURAL ENGINEERING, vol. 28, no. 8, August, 1947.

Tillage on a Vegetable Farm

By Harold Kellett

THESE remarks refer to a 1100-acre farm in the southeastern section of Pennsylvania. It is situated on clay loam soil. Some of it will bake so hard in the sun after a rain that you can hardly make a heel mark in it. On some of the ground we plant four crops a year, two of radish and two of spinach. Last year we grew about 400 acres of radishes, 170 acres of tomatoes, and 600 acres of spinach.

All of our soil is prepared with moldboard plows, about 8 in deep. Most of it is done with a five-bottom plow pulled by a track-type tractor. We test between nearly every crop and broadcast our fertilizer and lime, depending on crop needs. We go over it with a double-disk harrow and drag three or four times until we get it well pulverized as deep as possible.

From this point on we vary our tillage operations somewhat depending on the crop. For radishes, for example, we want a very fine, loose, spongy seedbed. On spinach, we do not want a spongy seedbed, but rather pack it several times to get it firm. Both of these crops are planted on beds. The beds are planted on 76-in centers, with about 64 in width of top surface for planting. The wheel tracks for the tractor are 4 to 8 in deep, depending on the weather conditions. On root crops such as carrots and parsnips we follow the plow with the subsoiler, so that we can get a deep seedbed for the roots to go straight down. We vary the compactness of the seedbed, depending on moisture conditions. If there seems to be plenty of moisture, we do not have the soil so firm, but if it is the dry season of the year, we pack it. For celery, we try to get the seedbed as deep as possible, using a heavy disk which is set to cut in as far as possible. For this crop we are considering using a large field rotary tiller.

Our cultivation varies with different crops. On spinach, which grows fairly fast, we do not cultivate any more than necessary to kill the weeds. It seems to do better when the ground is hard. If it should be necessary to get the weeds in spinach, we use knives which scrape along the top of the ground. The cultivator that does this is drawn by a trailer with a man riding on it. It does extra close work. For radishes, we use no cultivation. With carrots and parsnips, we use alfalfa steels set as close to the small plants as possible, and run them about 6 to 8 in deep. We use a tubular shield which goes over the row, and protects the young plants from the dirt thrown up by the teeth. If they are too weedy, we use a weed killer when the plants are small. On beets, we use knives and duck-foot cultivating teeth to cut off the weeds, and follow later with the duck feet to make a dust mulch on top of the soil. We don't go much deeper than an inch. For tomatoes, we prepare a deep mulch. They are transplanted with units mounted on tractors. Water is applied at the time of planting. They are cultivated as soon after planting as possible, using a rotary hoe guard alongside the row to break up the crusting of the soil caused by rain.

This paper was presented at a meeting of the Pennsylvania Section of the American Society of Agricultural Engineers, at The Pennsylvania State College, April, 1948.

HAROLD KELLETT is manager of Becker Farms, Bucks County, Pa.

This Problem of Agricultural Engineering Extension

By L. G. Samsel
MEMBER A.S.A.E.

THIS problem of extension — the conveying of factual and helpful information from the experiment stations and the laboratories of industry to the farm is a big one. Winning the acceptance and application of the information is even more of a problem.

Thousands of experiments are being conducted in the engineering, agronomic and other phases of agriculture. Many experiments have been completed, and the facts obtained are available to the public. Others continue year after year and conclusions can be drawn only on the currently indicated basis. In this respect, engineers and research people often feel themselves "on the spot".

What appears to be true now may be refuted by later experiments. It may not be possible to repeat tests under identical conditions. Temporary reports — even final reports — may be misinterpreted, misquoted, or overemphasized by others engaged in publicity or extension. With this in mind, the researcher is justifiably reserved in releasing his findings.

Very often it happens, however, that research projects under way are of definite interest to the public and especially to manufacturers who will be asked to provide certain materials and equipment needed for new methods ultimately proved worth while by tests. Where possible to publicize "investigations in progress", the interested public is prepared for the outcome. The idea will not be completely new to farmers who will utilize the new proven methods.

A contribution of the A.S.A.E. Committee on Extension — L. G. Samsel (chairman), M. R. Dunk, E. G. Johnson, C. N. Hinkle, C. V. Phagan, R. C. Shipman, J. M. Ferguson, A. H. Hemker, W. D. Hemker, J. F. Schaffhausen, and W. G. Kaiser.

L. G. SAMSEL is in charge of the educational division, J. I. Case Co.

Even known facts, sometimes known for years, are slow of acceptance. We cite two reasons for this:

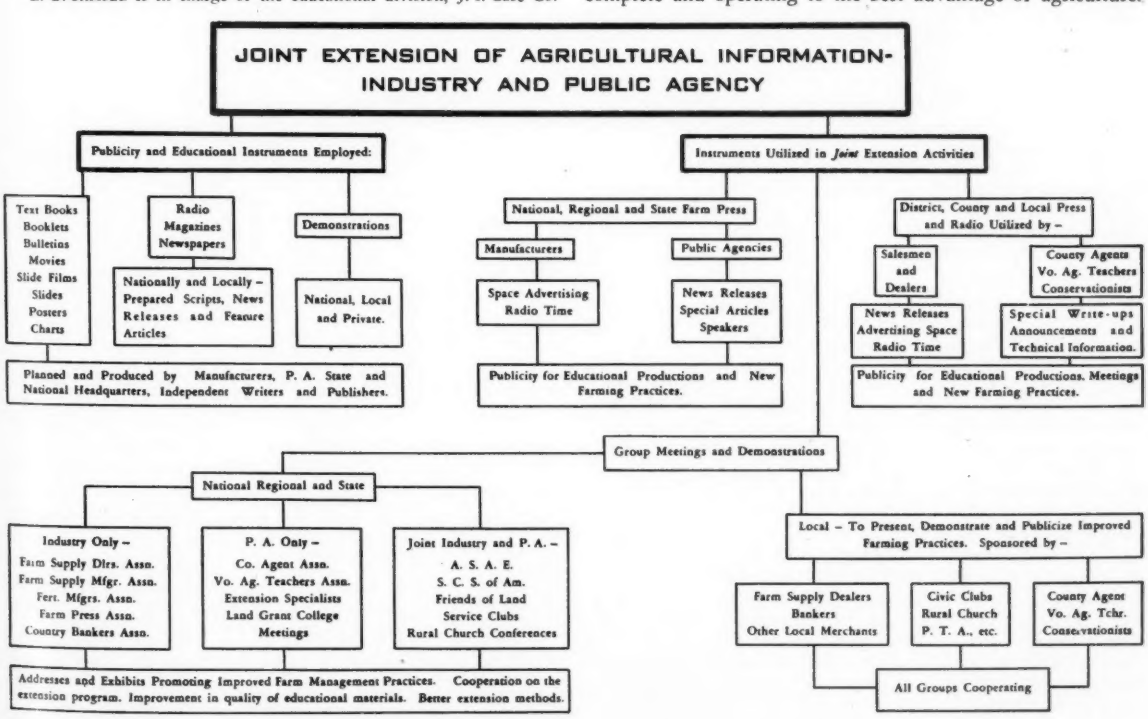
1 Our natural tendency to cling to old methods. Often this is a mere matter of habit or custom without scientific background, as, for example, the use of left-handed plows in some sections, or the practice of farming up and down hills and fencing on the "square" instead of contouring.

2 Poorly planned and ineffective publicity. Here is where extension enters in.

In the days of animal power, scientific agriculture was carried to the farm almost entirely by the various branches of the U. S. Department of Agriculture and the land-grant colleges with assistance from the farm press. During this period, the educational efforts of industry extended very little beyond the care, maintenance, and operation of machines. Farm machines as we think of them now had not come into general use. The idea of manufacturers giving intelligent and helpful counsel on the best selection and use of equipment came later with the general mechanization of agriculture.

Many manufacturers are today providing this good counsel to which we refer. Many are conferring with experiment stations and agricultural scientists on proven methods and publicizing the information gained in service and advertising literature. In a like manner, many experimental workers and research folk are conferring with industry — making known their projects — checking for practicability.

Public agency extension people—county agricultural agents, teachers of vocational agriculture, and extension specialists — are enlisting the aid of dealers and manufacturers in the extension program — in press publicity, in the holding of meetings, in demonstrations. But we have a long road to travel before a joint extension effort of public agencies and industry will be complete and operating to the best advantage of agriculture.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Demonstrations
National, Local and Private.
Planned and Produced by Manufacturers, P. A. State and National Headquarters, Independent Writers and Publishers.
Instruments Utilized in Joint Extension Activities
National, Regional and State Farm Press
Manufacturers
Public Agencies
Space Advertising Radio Time
News Releases Special Articles Speakers
Publicity for Educational Productions and New Farming Practices.
District, County and Local Press and Radio Utilized by –
Salesmen and Dealers
County Agents Vo. Ag. Teachers Conservationists
News Releases Advertising Space Radio Time
Special Write-ups Announcements and Technical Information.
Publicity for Educational Productions, Meetings and New Farming Practices.
Group Meetings and Demonstrations
National Regional and State
Industry Only –
Farm Supply Dlrs. Assn.
Farm Supply Mfgr. Assn.
Fert. Mfgrs. Assn.
Farm Press Assn.
Country Bankers Assn.
P. A. Only –
Co. Agent Assn.
Vo. Ag. Teachers Assn.
Extension Specialists
Land Grant College Meetings
Joint Industry and P. A. –
A. S. A. E.
S. C. S. of Am.
Friends of Land
Service Clubs
Rural Church Conferences
Addresses and Exhibits Promoting Improved Farm Management Practices. Cooperation on the extension program. Improvement in quality of educational materials. Better extension methods.
Local – To Present, Demonstrate and Publicize Improved Farming Practices. Sponsored by –
Farm Supply Dealers
Bankers
Other Local Merchants
Civic Clubs
Rural Church
P. T. A., etc.
County Agent
Vo. Ag. Tchr.
Conservationists
All Groups Cooperating

CHART PREPARED BY COMMITTEE ON EXTENSION, AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

This picture illustrates a joint "extension" activity on the part of a local farm machinery dealer, a county agricultural agent, a soil conservationist, and a vocational agriculture instructor. The particular demonstration project is the construction of a farm pond

The accompanying chart attempts to indicate the various agencies either charged directly with extension work or which can assist in the extension program. Charted first are the most common educational instruments at our disposal. The chart then suggests the joint or cooperative use of these publicity tools moving step by step from the national or headquarters phase to the locality where extension takes effect.

Looking at the chart, one can better visualize the possibilities of joint extension activities. Let's consider meetings of national organizations: Manufacturing groups might well bring in nationally known public agency men to discuss the opportunity industry has in promoting better farming methods. Public agency groups might benefit by having a manufacturer on their programs.

How about the national press, farm papers, and the agricultural sections of big dailies? This is perhaps the oldest and best-read source of agricultural information, but the information is of necessity sketchy. It cannot be too specific because of wide coverage. Such publications have an opportunity to call the attention of their readers to detailed information available in bulletin form and some do this very effectively. Many publicize, free of charge, both government publications and the educational productions of industry.

The state or regional farm paper and the local newspaper will be found in most farm homes. Such publications keeping in close touch with the state experiment station and publicizing its findings are giving good service to their readers. Those reporting on actual and successful farm applications of new practices are giving still better service. They are "extending" factual information.

But how about the people who provide the fertilizer, the building materials, the machines and utensils needed? Where can they enter the field of local extension? Referring specifically to the press, many manufacturers are already employing informative copy in their national and state paid advertising space — calling attention to instructive booklets available through dealers—suggesting state and federal extension publications. Some even prepare special publicity release materials for dealers. But even without help from headquarters, many dealers report new farm practice news to the local paper and associate their products with new advocated practices in their paid advertising.

Alert dealers are approaching the county agent, the teacher of vocational agriculture, the soil conservationist, the forester — becoming informed and lending assistance in publicity, the holding of meetings and demonstrations. Alert county agents and the other public agency people are working with dealers, other local business men, civic and religious organizations to bring about the general adoption of more scientific agricultural methods.

Among the organized groups who can be most effective in bringing about joint extension effort are those national organizations to which belong representatives of both industry and public agencies. We refer to the American Society of Agricultural Engineers, the American Society of Agronomy, the Soil Conservation Society of America, Friends of the Land, service clubs, rural church conferences, and parent-teachers associations. In these groups we meet on common ground. We can offer helpful suggestions to one another — help to correlate agricultural extension activities.

This review would not be complete without a few "do's" and "don'ts" to industrialists and public agency folk who contemplate more effort toward joint extension activities. The following is directed to representatives of industry, including dealers:

1 Forget the immediate sale of goods, especially your own products, in your contacts with USDA and state experiment stations, state colleges, county agents, teachers and others in public service. Think of *service* to agriculture and to your community. Do not embarrass people in public service.

2 Join with your competitor, if he is cooperative, in promoting better farming.

3 Take a sincere interest in how your machines or materials can be made more useful and productive to the customer. This will help you and help him. This is extension.

4 Look ten years or more ahead in your business. Build up prosperity for those whom you serve and you yourself will prosper.

5 Manufacturers should listen well to the ideas, suggestions, and findings of government research men and engineers. Like privately employed engineers, these fellows have good and bad ideas — need to make contacts —can be helpful.

And here are suggestions to those who work for "Uncle Sam", the state, the county, or the local school board:

1 Remember that those who serve agriculture by making available needed machines and materials have ideas and problems, too. You can profit — can better serve agriculture — by conferring with them.

2 Strive to be impartial and open minded in your contacts with manufacturers and suppliers. That "gadget" you have invented may be good, but have you considered all related manufacturing and distribution problems? Possibly some other machine already in common use would, with some modifications, do the work just as well.

3 Good businessmen are anxious to serve the public. They will gladly work with you in extending agricultural information. But make clear your position. You can't help sell their merchandise, but together you can publicize and demonstrate better farming practices.

Some Runoff Control and Moisture Conservation Possibilities

By R. B. Hickok, I. D. Mayer, and H. Kohnke
MEMBER A.S.A.E. MEMBER A.S.A.E.

THIS paper reports progress of an experiment to determine the seasonal amounts and periodic high rates of surface runoff from small agricultural watersheds, under prevailing farming practices and under a conservation system. Comparison of prevailing farming practices and conservation systems is intended primarily to provide information on the overall influences on runoff of a generally improved agriculture, which may be expected to prevail within a few years. The experiment is conducted jointly by the research branch of the Soil Conservation Service, U. S. Department of Agriculture and the agricultural experiment station of Purdue University, on a farm near Lafayette, Indiana. The land conditions, climate, and type of agriculture are representative of a large part of the eastern section of the corn belt.

THE EXPERIMENT

Rainfall and runoff are measured for 20 small, natural watersheds. This number includes 14 watersheds which are rotation-cropped, four in permanent pasture, and two in woodlots. Twelve watersheds in close proximity, ranging from 2 to 3.5 acres, are used in the rotation-crop experiment, for which results are reported in this paper. These 12 watersheds are included in three groups, representing three crops each year. Each of the three crop groups is subdivided into two pairs, selected to include similar ranges of natural characteristics, for two samples each of both the prevailing and conservation farming systems. This design may be expressed: 3 crops×2 treatments ×2 replicates=12 watersheds.

The crop rotation from 1942 to 1945 was corn - wheat - meadow (one year). Soybeans were added beginning in 1946, changing the rotation to corn - soybeans - wheat - meadow (one year). With the 4-yr rotation, three of the four crops are represented each year, each crop in the sequence being progressively skipped in successive years.

The prevailing treatment includes straight-row seeding, moderate* applications of commercial fertilizers to corn and wheat, mixed red clover and timothy seeding for the meadow, and partial removal of crop residues. The conservation treatment includes contour seeding, heavy† applications of commercial fertilizers to corn and wheat, and manure plowed under for corn, the addition of alfalfa and alsike to the meadow seeding, and return of all residues.

The watersheds are covered by an intense network of recording rain gages, and each watershed has a type H runoff-measuring flume[1‡] equipped with a water-level recorder. This provides continuous time-rate measurements of rainfall and runoff. Each of the runoff-measuring stations is also equipped with an automatic aliquoting device[2] which provides samples for laboratory determinations of the soil and fertility components of the runoff.

The rotation-cropped watersheds are located on the Purdue-Throckmorton Farm 8 mi south of Lafayette. Their soils, which have been classified in the Carrington group, were developed from calcareous till under prairie vegetation. The soil profiles are moderately well drained. The predominant surface slopes of the watersheds range from about 2 to 5 per cent. The topsoils of the watersheds have been estimated to be 30 to 40 per cent eroded, and their present average depths range from approximately 8 to 10 in.

The U. S. Weather Bureau[3] estimates the average annual rainfall of the locality to be about 38 in. About 48 per cent of this amount falls from May through August. Rainfall intensity data are limited. The available information[4] indicates an average expectancy for northern Indiana of three to four storms per year totaling from 1 to 2 in of rain falling at "excessive" rates**. Around 95 per cent of all "excessive" rainfall recorded has occurred from May through September. About 75 per cent has occurred during June, July, and August,

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AUTHORS' ACKNOWLEDGMENT: The authors appreciate the contribution by G. D. Bedell, former soil scientist, Soil Conservation Service, in compiling part of the erosion loss and crop yield survey data reported. Appreciation is also expressed for valuable assistance in planning of the experiment and counsel in its conduct by G. D. Scarseth former head of agronomy department, Purdue Agricultural Experiment Station.

*Fertilization of prevailing practice watersheds has included 125 lb per acre of 0-14-7 or 2-12-6 applied to corn with planter, and 150 lb per acre of the same analyses drilled with wheat.

†Fertilization of conservation treated watersheds has included 1,000 lb of 8-8-8 and 6 tons of manure per acre plowed under for corn, plus 125 lb of 0-14-7 or 2-12-6 applied with planter; and 400 lb per acre of 0-14-7 or 2-12-6 drilled with wheat, plus 100 lb of 10-6-4, or 4 tons of manure per acre as spring topdressing.

‡Superscript numbers refer to appended references.

**One-quarter (0.25) in in 5 min, plus an additional 0.01 in for each additional minute of duration, or more.

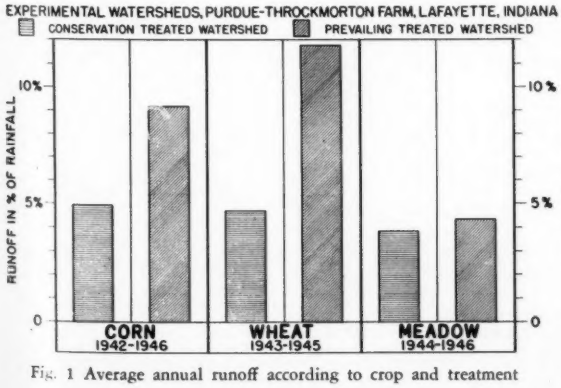

Fig. 1 Average annual runoff according to crop and treatment

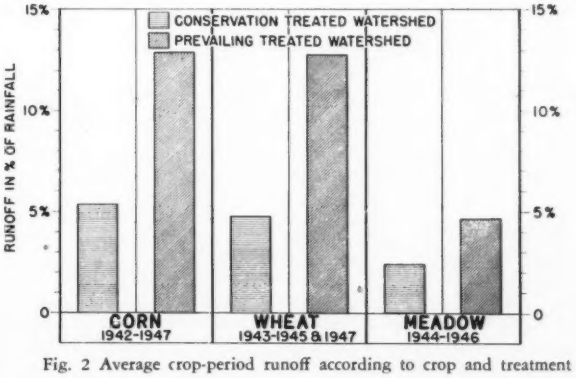

Fig. 2 Average crop-period runoff according to crop and treatment

and 30 per cent during each of the months of June and July.

RESULTS

The average rainfall on the watersheds during the period of the experiment has been 36.4 in, with a minimum of 30.4 in in 1944 and a maximum of 44.8 in in 1945. The period has included 3 yr with rainfall significantly below, and 2 yr significantly above the record mean for the locality. Table 1 gives the numbers of storms and total amounts of "excessive" rainfall for each of the years of the experiment.

TABLE 1 ANNUAL NUMBER OF STORMS AND AMOUNT OF RAINFALL AT EXCESSIVE RATES, 1942-1947

Purdue-Throckmorton Farm, Lafayette, Indiana

Year	Number of storms	Total amount, in
1942	7	8.86
1943	5	2.83
1944	4	2.42
1945	9	7.19
1946	2	1.48
1947	7	4.26

Table 2 gives a tabulation average of annual and crop-period runoff from experimental watersheds under prevailing practices and conservation treatments. Totals of runoff are reported in terms of percentage of the total rainfall. This reduces the variance by years and by individual watersheds, and is believed to make the data more usable.

Fig. 1 illustrates the average runoff and Fig. 2 shows the average crop-period runoff from corn, wheat, and meadow from prevailing practice and conservation treated watersheds for the period of the experiment. The crop-period runoffs are more significant than the annual totals from the standpoint of moisture conservation.

The manner in which the total runoff losses have been distributed over the crop rotation periods is illustrated by Fig. 3, showing an accumulation graph of the runoff from a pair of watersheds, one under the prevailing farming practice and one under the conservation treatment, for years 1942 through 1944.

Table 3 lists all peak runoff rates exceeding 2 iph (inches per hour) and the attendant conditions, recorded from 1942 through 1946. These results are based not only on the twelve watersheds included in the rotation-crop experiment previously described, but also two additional cropped watersheds and two permanent pasture watersheds on the Throckmorton Farm, and two permanent pasture and two woodlot watersheds located on the Purdue Dairy Experiment Farm. The latter are on poorly drained, timbered upland soils. The soil and other features of the watersheds are described in Table 3.

Results of the erosion studies on the rotation-crop watersheds through 1946 have been previously published[5]. They may be summarized briefly as follows:

Total Solids losses measured so far have been relatively low, compared with those reported from other experiments. Solids losses totaled about 5 tons per acre (4 tons from corn) from prevailing treated watersheds, and about 2 tons per acre from the conservation treated watersheds, for the first 3-yr crop rotation period. The watersheds in corn under conservation treatment in 1945, in the second cycle of the rotation, lost only one-third as much solids as when these same watersheds were in corn in 1942; whereas solids losses from the prevailing treated watersheds were about 75 per cent as high in 1945 as in 1942.

Organic Matter in the eroded material has averaged approximately twice the proportion of organic matter in the field soils. It has been estimated that it would require approximately 2.5 tons of barnyard manure per acre to replace the organic matter eroded from the prevailing treated watersheds during the first 3-yr crop rotation period and approximately 0.75 ton per acre to replace that lost from the conservation treated watersheds during the same period.

Nitrogen losses average about three times as high in proportion to the eroded solids as the nitrogen content of the surface soils. The nitrogen losses in runoff were more closely related to the total runoff than to the solids lost. Nitrogen losses from watersheds in corn under conservation treatment were one-fourth as much as those under prevailing treatment in 1942, and one-sixth as much in 1945, in spite of the fact that the latter watersheds received heavy applications of nitrogen fertilizers and manure.

Phosphorus in weak acid-soluble exchangeable, and organic forms in the runoff bore similar relationships to the solids

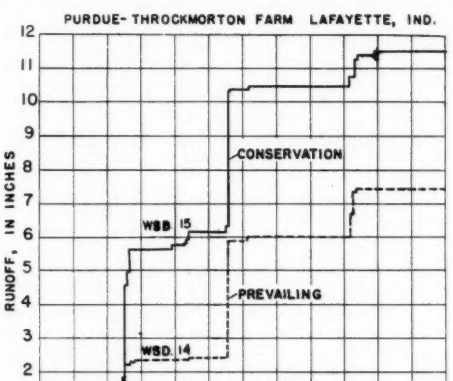

Fig. 3 Accumulated runoff during a crop rotation period from a prevailing treatment and a conservation treatment watershed

TABLE 2. AVERAGE ANNUAL AND CROP-PERIOD* RUNOFF FROM EXPERIMENTAL WATERSHEDS UNDER PREVAILING AND CONSERVATION TREATMENTS

Purdue-Throckmorton Farm, Lafayette, Indiana

Per Cent of Rainfall

Crop	Treatment	1942 Annual	1942 C. P.	1943 Annual	1943 C. P.	1944 Annual	1944 C. P.	1945 Annual	1945 C. P.	1946 Annual	1946 C. P.	1947 Annual	1947 C. P.
Corn	Prevailing	14.35	24.07	14.70	20.44	3.56	0.20	17.07	18.89	5.20	3.95	5.95	9.80
	Conservation	7.82	12.74	9.08	12.89	2.58	0.04	2.70	3.52	2.42	1.34	1.75	1.32
	Difference	6.53	11.73	5.62	7.55	0.98	0.04	14.37	15.37	2.78	2.61	4.20	8.48
Wheat	Prevailing	2.31	3.80	15.69	18.16	6.95	8.80	12.78	15.41			5.36	6.54
	Conservation	Started in '43		10.69	11.68	1.34	1.61	2.15	1.07	None†		2.34	2.90
	Difference	—	—	5.02	6.48	5.61	7.19	10.65	14.34			3.02	3.60
Meadow	Prevailing	2.48	—	11.26	8.08	6.50	4.49	3.62	4.70	2.90	4.62		
	Conservation	Started in 1944				4.56	2.79	1.32	1.86	1.89	2.32	None†	
	Difference	—	—	—	—	1.94	1.70	2.30	2.84	1.01	4.30		

*Crop periods: Corn — From spring plowing of meadow to corn harvest.
Wheat — From seeding wheat in fall, to harvest ensuing year.
Meadow — From wheat harvest previous year, to spring plowing for corn ensuing year.

†Not grown on watersheds.

losses and total runoff as were found for nitrogen. Their total from the prevailing treated watersheds for the rotation period was about four times the total from the conservation watersheds.

Potassium in the runoff has been relatively lower than nitrogen and phosphorus. However, the total amount of available potassium lost in the runoff from the watersheds under the prevailing treatment during the crop rotation period was about equivalent to that applied in commercial fertilizers. The amount lost from the conservation treated watersheds was only one-half that lost under the prevailing system. On the other hand, the conservation treated watersheds had received about ten times as much potassium as the prevailing treated watersheds in the applications of fertilizer.

DISCUSSION AND ANALYSES

The occurrence of peak runoff rates which exceeded 2 iph from the experimental watersheds may be considered an index to the probable influences of crops and soil management on flash floods and, in the case of corn and probably other open cultivated crops, a major part of the erosion losses[5]. Table 3 shows that all runoff rates exceeding 2 iph from the rotation-crop watersheds occurred when they were in corn. Thus it appears that the expectancy of critical runoff rates from rotation cropland is to a high degree dependent upon the frequency of corn (and probably other clean-tilled crops) in the crop rotation. If the frequency for runoff peaks of 2 iph or more is to be estimated on the basis of the frequency of corresponding rainfall intensities, the runoff frequencies may bear a ratio to rainfall frequencies equal to the number of open-tilled crops in the rotation divided by the length of the crop rotation. Thus, with a 3-yr rotation including one year of corn, the maximum rainfall intensity expected once in 5 yr may be related to the peak runoff rate that should be expected to occur once in 15 yr.

It may be noted also that of the 17 occurrences of runoff rates exceeding 2 iph from watersheds in corn, thirteen were from prevailing treatment watersheds and only four were from those under the conservation treatment. Thus it appears that the conservation treatment has reduced the frequencies of these high runoff rates to about one-third of their frequency from watersheds under the prevailing treatment. However, there is no evidence that the maximum heights of the peaks from these very small watersheds may be substantially reduced by the conservation treatment when they do occur. The high runoff rates from conservation treated land in corn have occurred early in the season before contouring became very effective, because cultivation ridges had not been fully developed, or in cases of very heavy rainfall, when the contours have broken over. This definitely indicates the importance of the development of contour ridges and furrows as early as possible by planting and tillage operations and their maintenance throughout the season. It also indicates that some further conservation measures will be required for the maximum control of erosion and water losses from land in open-tilled crops.

Fig. 1 shows the average annual runoff losses from corn and wheat to have been approximately 9 and 12 per cent of the total rainfall, respectively, from watersheds under prevailing treatment. Both were reduced to approximately 5 per cent by the conservation treatment. The latter amounts were only slightly more than the losses from watersheds in meadow. The conservation treatment did not materially affect the average water losses from the meadow watersheds.

The runoff averages from both wheat and meadow watersheds under the conservation treatment were greatly influenced by the 1943 spring losses, when a total of approximately 13 in of rain fell in May, or about a third of the "normal" annual rainfall. During this and other similar high-rainfall

TABLE 3 - RUNOFF PEAK RATES EXCEEDING 2 IPH, AND THEIR ATTENDANT CONDITIONS, FROM 20 SMALL AGRICULTURAL WATERSHEDS AT LAFAYETTE, INDIANA, 1942-1946

Runoff and rainfall rates, in./hr.				Antecedent rainfall, in.				Watershed cover and conditions					Watershed characteristics						
											Last prior tillage					Slopes, percent		
Peak runoff[1]	Maximum 5-min. rainfall	Maximum 10-min. rainfall	Ratio of peak runoff to max. 10-min. rainfall [2]	6-hour	12-hour	24-hour	Since last tillage	Crop	Treatment [4]	Date of storm	Date	Type	Watershed No.	Size, acres	Prevailing soil type [5]	Soil organic content, percent	Range	Prevailing	Erosion, "A" horizon removed
7.33 [3]	8.10	5.94	1.24 [3]					Corn	P	6/6/42	6/5	1st cult.	15	3.59	24	3.6	0-5	3.0	40
4.68	9.00	6.90	0.71			0.08	2.82	Corn	P	8/14/45	7/5	2nd cult.	15	3.59	24	3.6	0-5	3.0	40
4.18	6.60	5.88	0.71				2.91	Corn	P	6/6/42	6/5	1st cult.	10	2.06	Mixed	3.6	0-4	2.5	40
3.90	5.40	4.50	0.87	0.30	0.30	0.30	4.20	Corn	P	7/20/42	6/23	2nd cult.	15	3.59	24	3.6	0-5	3.0	40
3.89	8.10	5.94	0.65					Corn	P	6/6/42	6/5	1st cult.	13	3.02	22	4.4	0-2.5	1.0	30
3.77	8.10	5.94	0.64					Corn	C	6/6/42	6/5	1st cult.	14	2.85	24	3.6	0-6	2.5	40
3.31	8.10	5.94	0.56					Corn	C	6/6/42	6/5	1st cult.	18	3.24	Mixed	3.9	0-7	2.5	30
3.30	4.56	3.78	0.87			0.39	2.22	Corn	C	7/4/43	6/19	1st cult.	7	1.96	24	3.3	0-7	4.5	40
3.01	4.56	3.78	0.80			0.39	0.41	Corn	P	7/4/43	7/3	2nd cult.	8	1.96	24	3.3	0-8	3.0	40
2.98	6.72	5.34	0.56				3.31	Corn	P	8/14/45	7/6	2nd cult.	10	2.06	Mixed	3.6	0-4	2.5	40
2.89	6.12	4.26	0.68	0.17	0.17	0.17	4.30	Corn	P	7/20/42	6/23	2nd cult.	10	2.06	Mixed	3.6	0-4	2.5	40
2.84	4.32	3.90	0.73			0.30	0.30	Corn	P	7/4/43	7/3	2nd cult.	5	2.87	22	3.4	0-7	2.0	20
2.76	5.16	3.30	0.84		0.74	0.74	3.09	Corn	P	7/13/42	6/23	2nd cult.	15	3.59	22	3.6	0-5	3.0	40
2.55	4.56	4.14	0.62					R past.		6/16/43			31	1.65	Mixed		0-5	6.0	30
2.36	6.72	5.76	0.41	0.07	0.07	0.07		R past.		8/14/45			20	2.64	24	4.4	0-2	6.0	50
2.19	5.40	4.50	0.49	0.30	0.30	0.30	4.20	Corn	C	7/20/42	6/23	2nd cult.	14	2.85	24	3.6	0-6	2.5	40
2.19	5.40	4.50	0.49	0.30	0.30	0.30	4.20	Corn	P	7/20/42	6/23	2nd cult.	13	3.02	22	4.4	0-2.5	1.0	30
2.19	4.20	3.96	0.55				7.04	Corn	P	9/22/45	7/5	2nd cult.	15	3.59	22	3.6	0-3	3.0	40
2.13	2.76	2.34	0.91			0.06	1.13	Corn	P	6/19/46	6/17	1st cult.	8	1.96	24	3.3	0-8	3.0	40

[1] All runoff rates corrected for storage due to impounding of water by the measuring device, except from Watershed No. 31 where storage is small.

[2] Concentration period of all watersheds may be estimated to be 10 min. (within usual accuracy of estimates of concentration periods) and the ratio of the peak runoff rate to the maximum 10-min. rainfall rate may be considered approximately equivalent to the coefficient "C" in the "Rational Formula" for estimating peak runoff from small watersheds.

[3] Peak rate greatly exceeded next highest on record and was affected by a very unusual rate of rise in depth of flow and consequently included a very large storage. There is no indication of an erroneous record. The rainfall rates were exceedingly high at the beginning of the storm and probably resulted in rapid puddling and sealing of the surface soil which had been cultivated the previous day. It appears that the phenomenal rate of rise and very high peak rate of runoff may have resulted from a temporary storage in corn rows which were cultivated across the general direction of drainage and a subsequent release when these rows broke over. The actual concentration time appeared to be between 5 and 10 min. Even related to the 5-min. maximum rainfall rate recorded, the coefficient of runoff exceeded 0.9.

[4] P - Prevailing treatment; check-row planting, and cultivation with usual fertilization. Corn following red clover-timothy meadow.
C - Conservation treatment; contour drilled and cultivated, increased fertilization and return of organic residues to the soil, corn following mixed meadow with alfalfa, red clover, alsike, and timothy. Differential treatment began in 1944.

[5] Soil type mapped on 50 percent or more of the area of the watershed. "Mixed" indicates that no single type exceeded 50 percent of area and includes Carrington, Dana, and Raub silt loams with Floyd silty clay loam (generally poorest drainage). 22 - Raub silt loam (slow drainage). 24 - Carrington silt loam (good drainage).

periods the runoff from conservation treatment watersheds in wheat and meadow has approached, and in a few cases exceeded, the runoff from the wheat and meadow watersheds under prevailing treatment. While the peak rates of runoff have been substantially reduced by conservation treatment, when the soil has become saturated, the runoff has endured over longer periods, and has included substantial amounts of water which have moved laterally through the soil. The total runoff has been little or no less from the conservation treated watersheds in close-growing crops than from those under the prevailing treatment during extremely wet periods.

There is no means of knowing from this experiment how the retardation of runoff from the headlands may affect the flood peaks at some distant point downstream in a large drainage system. It is evident from the data herein presented, however, that the conservation system may be expected to substantially reduce or practically eliminate floods resulting from "flash" storms. To that extent it can be expected to reduce the frequencies of floods on major streams.

Flash rainfalls produce the flood peaks on minor tributaries, and the conservation treatment, under conditions similar to those of this experiment, may be expected to materially reduce both the peaks and the frequencies of upstream floods. It may be born in mind that cost of rural damage from floods of small streams is many times that of the more publicized urban damages resulting from floods on larger streams[6].

The utilization of conserved water for increased crop production is of prime agricultural interest. Increased crop yields shown in Table 4 have been due mainly to the combination of increased fertilizer application and increased available moisture†† which are interacting influences. In other words, the return from increased fertilizer applications changes with the amount of moisture available and vice versa. For the purposes of this experiment, it has been desired to evaluate the over-all influences of a generally improved agricultural system on the runoff and erosion losses, rather than the effects of specific control practices. However, as a basis for evaluation of its effect on crop yields, the factor of available moisture, or more directly the reductions of runoff, may be considered as an independent variable over a number of years; while other factors of fertility, soil condition, etc., remain practically constant or follow definite trends. In the case of the corn yields, there appears to be sufficient data to establish a regression of crop yield increases for the individual years on the corresponding reductions in crop-period runoff by the conservation treatment.

††Changes in soil structure as the result of the conservation treatment may have contributed to increased crop yields. However, this influence would be expected to be manifested by a time trend for increased yields which is not yet apparent.

TABLE 4. CROP YIELDS FROM EXPERIMENTAL WATERSHEDS
Purdue-Throckmorton Farm, Lafayette, Indiana

Year	Treatment	Yields Per Acre, 1942-1947 Corn, bu	Wheat, bu	Hay, lb	Soybeans, bu
	Conservation	92	Started		
1942	Prevailing	67	in	Started	
	Difference	25	1943		
	Conservation	88	24	in	Started
1943	Prevailing	55	15	1944	
	Difference	33	9		in
	Conservation	70	29	3400	
1944	Prevailing	48	25	2300	
	Difference	22	4	1100	1946
	Conservation	122	43	5206	
1945	Prevailing	71	37	3321	
	Difference	51	6		
	Conservation	128	None*	Crop	8.2
1946	Prevailing	101		Failure	11.7
	Difference	27	—	—	-3.5
	Conservation	111	27	None*	37
1947	Prevailing	83	27		30
	Difference	28	0	—	7

*Not grown on the experimental watersheds; skipped because of change in crop rotation from 3 to 4 years.

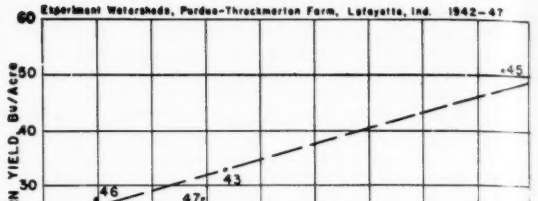

Fig. 4 Relationship of corn yield increases by conservation practices to the reductions in runoff during the crop period

Plotting the runoff reductions and corresponding yield increases as rectilinear coordinates, Fig. 4 indicates a positive, linear correlation of a fairly high degree for the ranges of runoff reductions so far experienced, with an exception of 1942. It was not until after 1942 that it became apparent to the experimenters that the density of plant population might be a factor limiting yield when fertility and available moisture were materially increased. In subsequent years, the seeding rate on the conservation treated watersheds was increased over that on the prevailing practice watersheds to obtain a more nearly uniform and efficient ear weight under both treatments[7]. It is believed that insufficient population imposed a ceiling on the 1942 yield from the conservation watersheds and to a considerable extent caused the deviation of the 1942 results from the line of those for other years. This belief is upheld by the fact that the 1945 point, representing the same group of watersheds as were represented in 1942, does fall in good line with the other four years. If we may accept this assumption and compute the linear regression, omitting the 1942 point, we obtain the expression

$$Y = 22.9 + 5.84X$$

where Y = the corn yield increase in bushels per acre

X = the reduction in runoff during the growing period by the conservation system, in inches of water.

Increased moisture available to the crop as a result of reduced runoff during the growing period has contributed an average of 5.84 bu per acre per inch, to the net yield increases, in a combination with increased available plant nutrients, probably better soil aeration, etc. Pending the availability of more data, it is believed this equation provides a usable tool for estimating the corn yield increases that may accrue from the type of conservation system under study for similar conditions to those of the experiment.

AN ESTIMATE OF A MOISTURE CONSERVATION AND UTILIZATION POTENTIAL

The senior author has previously presented to the American Society of Agricultural Engineers[8] the proposal that estimates of available moisture, based on hydrologic investigation, should precede plans for agricultural developments, for appraisal of their possible return. Accordingly, the following analysis is offered as an example of such an estimate.

Fig. 5 shows a graph of points relating the crop-period reductions in runoff in per cent of the crop-period rainfall for each season of the experiment to the crop-period rainfall. It may be seen that these points indicate a positive linear correlation of these values. Computation of their regression results in the expression

$$R = 0.97P - 11.36$$

when R = the crop period runoff reduction in per cent of the crop period rainfall

P = the total crop period rainfall, in inches.

This is a quadratic relationship of the actual runoff reduction to the rainfall, and when

X = the runoff reduction in inches,

$R = X/P \times 100$, and $X = 0.0097P^2 - 0.1136P$.

A frequency distribution of corn crop-period (May - September) rainfall for northern Indiana (Fig. 6) has been compiled from all available records[9]. With this distribution data and the above equation for the runoff reduction in terms of total rainfall, a corresponding frequency distribution of runoff reductions by the conservation system, X, was estimated. From this information, a probable long-time mean runoff reduction was estimated to be 1.11 in per year. Entering this value into the equation derived from the experimental data relating yield increases to runoff reductions, indicates average annual increase in corn yields of 29 bu per acre, more or less. This is a rational estimate of the effects on corn yields which may be expected over a long period of time as a result of the complete conservation system of the experiment on similar land and under similar climatic conditions. Six to seven bushels of this estimated increase could not be expected without the expected reductions in runoff during the corn growing seasons.

This estimate is based on too limited data for a desirably high degree of confidence and may be considerably modified after a longer period of experimentation. However, it is considered that the present estimate illustrates an eventual usefulness of the experiment's results and provides some logical basis for judging the possible value of conservation farming from the standpoint of increased crop production. The prospect for increased corn yields would seem to offer support for an original premise of the experiment, that conservation farming will become common within a few years.

SUMMARY AND CONCLUSION

Progress is reported on agricultural hydrologic studies being conducted by the U. S. Soil Conservation Service (research branch) and Purdue University Agricultural Experiment Station, near Lafayette, Indiana. The objectives of this research include determinations of total runoff and occurrence of critical runoff rates from small agricultural watersheds in the eastern section of the corn belt.

Rainfall and runoff time-rate data are being measured in twenty small watersheds, including twelve in a rotation-crop experiment for which results to date are reported in this paper. Six years experimental results are available. While wide seasonal variations permit only general and approximate conclusions pending a longer period of experiment, results to date indicate present rates and amounts of runoff and important changes in these values which may result from the application of conservation practices.

The annual, and also the crop-period, runoff losses from watersheds in corn and wheat have been similar and about twice as much as those from watersheds in meadow, under the prevailing farming system. The experimental conservation treatment reduced water losses from corn and wheat to approximately those from meadow. The conservation treatment had little effect on the runoff totals from meadow watersheds. Both wheat and meadow watersheds lost heavily during protracted wet periods.

An array of 19 peak runoff rates exceeding 2 iph is given, with their attendant conditions. Of the seventeen such rates recorded from the rotation-cropped watersheds, all have been while the watersheds were in corn, thirteen under the prevailing treatment, and four under the conservation treatment. It is suggested that the frequency of critical runoff rates is directly related to the frequency of corn or other clean-tilled crops in the rotation. It is also pointed out that the conservation treatment has reduced the frequency of critical runoff rates; but not the maximum rates, because of their occasional occurrence before the contour ridges and furrows have been developed by the planting and seeding operations, or due to their subsequent breakdown.

It is expected that the conservation farming system may reduce frequencies of floods, but not necessarily the heights of flood peaks on major streams; and that both the frequencies and heights of upstream floods may be substantially reduced.

It is shown that moisture conserved by the conservation treatment has benefited crop yields. A relationship is demonstrated between runoff reduction and corn yield increases by the conservation over the prevailing system. Also, a relationship is shown between the runoff reductions during the corn growing period and the rainfall for the period. From these relationships and the rainfall records available, an estimate is made of a long-time average annual increase in corn yields which may be expected to result from the conservation system of the experiment. It is pointed out that this estimate, while approximate, demonstrates an eventual usefulness of the information being obtained from the experiment and provides some basis for planning until more conclusive data are available.

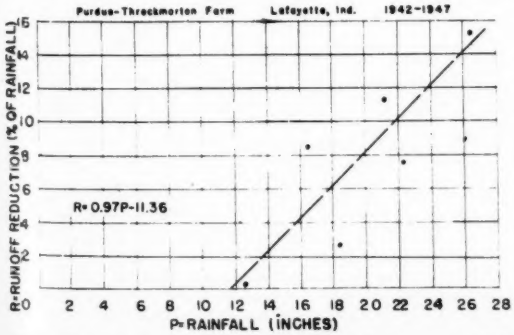

Fig. 5 Reduction in total crop period runoff from watersheds in corn by conservation practices related to total crop period rainfall

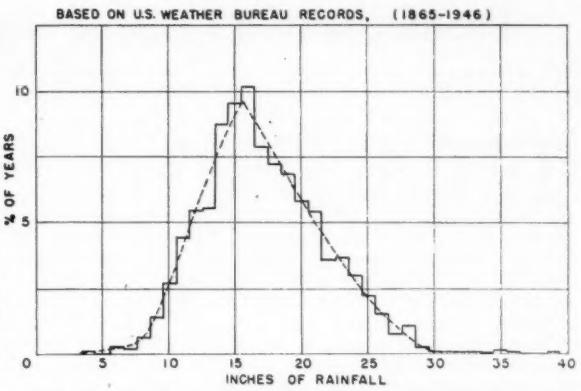

Fig. 6 Frequency distribution of rainfall during corn-growing period (May-September) in northern Indiana

LITERATURE CITED

1 Harrold, L. L., and Krimgold, D. B.: Devices for measuring rates and amounts of runoff employed in soil conservation research. USDA Soil Conservation Service Tech. Publ., 51 (Multilithed), 1943.

2 Kohnke, Helmut, and Hickok, R. B.: An automatic aliquot runoff sampler. Soil Science Society of America Proc., vol. 6, pp. 492-500, 1941.

3 Armington, J. H.: Climate of Indiana, USDA Year Book of Agriculture, p. 853, 1941.

4 Vischer, S. S.: Climate of Indiana, pp. 242-244. Indiana University Publications, Science Series No. 13, Indiana University, 1944.

5 Bedell, Glenn D., Kohnke, Helmut, and Hickok, R. B.: The effects of two farming systems on erosion from cropland. Soil Science Society of America Proceedings, vol. 11, pp. 522-526, 1946.

6 Cook, Harold L.: Flood abatement by headwater measures. Civil Engineering, vol. 15, no. 3, March, 1945.

7 Anonymous.: Corn stand and ear weight survey. Pennsylvania Agricultural Experiment Station (mimeographed).

8 Hickok, R. B.: Problems in agricultural hydrology. AGRICULTURAL ENGINEERING, p. 310, July, 1946.

9 Marvin, Charles F.: Climatic summary of the United States. Section 66, 1930; and Armington, J. H.: Climatological data, Indiana Section, vols. XXXVI-LI. 1931-1946. U. S. Weather Bureau

Problems of a College Ag Engineering Department

By Ray W. Carpenter
FELLOW A.S.A.E.

THE most immediate problem of a department of agricultural engineering in a land-grant college or university is the three-pronged one of staff, equipment, and building facilities. So far as staff is concerned, if my fairy godmother were to hand me the A.S.A.E. membership directory and say, "Here, of these 1500 names, you may take your pick", I would reply, "Thank you, Miss, but I can do no better than what I already have". And I make this statement in simple sincerity.

As regards equipment, due to the resourcefulness of two members of our staff who learned, not how to get surplus war equipment cheap, but how to get it free, we are in good shape in this category.

Our present building space leaves much, very much, to be desired. This morning we had on display the plans for our new building. While the money presently available is not sufficient to carry out these plans completely, we have reason to hope that substantial progress in this direction will be made in the near future.

Another problem concerns our relations with those with whom we work; farmers, research workers, county agricultural agents, vocational teachers, agricultural students, professional students. I have some ideas on this subject; I do not claim to have the answers.

Engineering has been defined as "utilizing the physical forces and materials of nature for social progress". The development of the atomic bomb satisfies this definition perfectly, so there may be some question as to the net direction of the progress, but we will not digress into this controversy. Briefly, engineering may be defined as applied physics.

Agriculture has been defined as "the application of biological principles to the production of foods and fibers", or, briefly, as applied biology.

But agriculture is more than this. It is a complete, integrated industry, and the structure of applied biology must be buttressed by two important auxiliary supports. One of these is the social sciences, including the fields of economics, distribution, and rural institutions. The second is the physical sciences, including the fields of power and machinery, structures, and many phases of soil and water management. In this area lies the field of agricultural engineering. Again, briefly, should not agricultural engineering logically be defined as "biological engineering"?

Here is a statement (I read it years ago) which has always intrigued me: "A successful farmer is a handy man with a sense of humus". I take the "sense of humus" to mean a love for and natural aptitude in the handling of living, growing things. In the "handy man" I imply a knowledge of, and facility with, the tools and techniques of agricultural production — in other words, a balanced blend of applied biology and applied engineering.

The gulf between the engineer and the biologist is too wide and deep to be explained merely by the accident of which dean got hold of the student first when he came to college. I am convinced that this gap is deeply rooted in fundamental differences in attitudes, aptitudes, and mental organization between individuals. Far-fetched, you say? Well, you know that the average biologist thinks of you as a queer introvert who is happy only when confronted with problems which can be solved to the fourth decimal place by means of slide rule, handbook, or exact formula. You engineers, on the other hand, think of the biologist as an amiable individual who, strange to say, is happy in the realms of speculation and hypothesis, who is satisfied if his correlations are just barely significant, and whose experiments must be randomized and replicated no end of times to yield even an approximate formula.

Both professions are alike in one thing—they both take refuge in a barbaric jargon which they refer to as their professional vocabulary.

This may be heresy, but I wonder how many of us engineers have ever considered whether the reason why biology is less exact and tangible than engineering might not be that biology, dealing with living rather than inorganic matter, is really the more complicated and difficult subject of the two? If this be treason, make the most of it!

In one area, however, we get along together beautifully. This is in our attitudes toward the social scientists. This is well stated in the old saying, "The economist is like the woofus bird, which looks and acts like a normal bird, except that he flies backward. He is blissfully indifferent to where he is going so long as he can see where he has been."

And yet, in our quiet moments, may we not wonder if the problems of production, distribution, prices and costs, minority pressure groups, propaganda and education, etc., are not the most important of all to all of us?

If there is a gap between the biologist and the engineer, someone should bridge it. I believe this is, in large measure, the responsibility of the agricultural engineer. I am even inclined to define the agricultural engineer as the liaison agent between agriculture and engineering. You may say that this is equally the responsibility of the biologist. On the technical level I agree. But so much of our job is working with and for people who are biologists at the application level rather than the technical. To name them again: farmers, county agents, vocational teachers, home demonstration workers, agricultural students; if anybody is to cross the barrier between these workers and ourselves, it is up to us.

How are we going to do it? Fortunately most of us grew up on farms, and consciously or unconsciously absorbed a good deal from the other side of the tracks. Too, let us think of the fellow we work with as a fellow who is plenty smart in his own right, one from whom we can learn a lot. Maybe a little supplemental reading and study would be helpful, and, who knows, it might be interesting as well.

But one of these days and not so long from now, our places are going to be taken by the young men who are now in college. What can we do to best serve their interests and, through them, and even more important, the interests of agriculture? We here at the University of Maryland want our graduates to be as well trained technically as the graduates from the standard engineering courses of study. We also want them to be well grounded in basic and applied biology. We believe that this is too big an assignment to be covered in a four-year curriculum. We have accordingly set up a five-year combined curriculum in agriculture-engineering. The graduate from this course of study will have a degree in civil, electrical, or mechanical engineering. He will also have a degree from our college of agriculture. In addition to the prescribed engineering subjects he will have taken twelve semester hours in agricultural engineering, four hours in botany, four in zoology and nineteen in basic agricultural subjects.

We are aware that this type of curriculum is not universally approved. We do believe that the present trend is in this direction. In any event, we believe in it and propose to carry on with it.

The foregoing has not exhausted the list of our problems. One more problem; tell us the answer, if you have it. This is it: How do we explain to all those who ask us for help that we simply do not have the time to do everything they ask, and still keep their friendship?

An address before a meeting of the Washington (D.C.) Section of the American Society of Agricultural Engineers, College Park, Md., March 5, 1948.

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Design of a Terrace System from Hydrologic Data

By Dwight D. Smith
MEMBER A.S.A.E.

HYDRAULIC data may be used in the design of a terrace system after two of the main features of design are satisfied from other than a hydrologic standpoint. These two features are spacing and channel grade. The criterion for their dimensions is soil movement. When they are established, the runoff rate, channel cross section area, ridge height, limiting terrace length, channel retardance, and outlet size may all be determined from hydrologic or hydraulic data. Terrace ridge and channel side slopes are of course modified by the type of agricultural and farming practices in use for the area under consideration. This paper will discuss the evaluation of those factors directly related to the hydrologic phase of design. The data used were secured on the Shelby soil at the Soil Conservation Experiment Farm, Bethany, Mo., during the period 1930-42. Overall planning of a water-management system including outlet type and location will not be considered in this paper.

RATE OF RUNOFF FOR INDIVIDUAL TERRACES

The rate of runoff for an individual terrace is a function of rainfall, soil, crop, land slope, and terrace spacing, grade, and length. By limiting this discussion to data from the Soil Conservation Experiment Farm, Bethany, Mo., rainfall and soil type will be constant for the other variables.

Spacing. A variation in the spacing of a terrace will affect the size of its drainage area. Thus any effect on rate of runoff from a variation in spacing may be reflected by the area factor. Rate of runoff in cubic feet per second is generally considered to vary as the drainage area in acres to some power less than one. The range of values for the exponent is from 0.8 to 1.0, depending on the size group of the drainage areas under consideration. This is due to the restricted area generally covered by an intense rain storm and the decrease in intensity with an increase in time. For the smaller drainage areas the magnitude of the exponent is more nearly unity. Hobbs[1]* has considered this exponent unity for terraced areas of 40 acres or less. As terrace spacing is predetermined for a given land slope, based on measured soil movement and observation of terraces in operation, spacing is generally not a design variable. In this study Missouri spacing recommendations have been used[5]. They are based on the measured soil movement and loss from the six spacing-study terraces on the Bethany Experiment Farm, with some modification considered desirable from observation of terraces in operation on the farms of the state.

Grade. The terrace channel acts as a temporary storage basin which is subject to unequal rates of inflow and outflow. The inflow rates for a given soil are affected by rainfall amount and intensity, land slope, cover, etc., whereas the outflow rates are affected significantly by the grade of the channel as well as the inflow rate. This is illustrated in Fig. 1, in which the ten maximum rates of runoff as measured during the 9 yr of the terrace grade study have been plotted. Maximum discharge rates for the 4-in uniform grade and the 1 to 4-in variable grade are practically equal for a 10-yr frequency runoff (plotting point equal to 0.1). For the 8-in grade the rate was 28 per cent higher than for the 4-in grade, whereas, for the 2-in and level grades the rates were, respectively, 83 and 52 per cent of the rates for the 4-in grade terrace. These ratios, with interpolated values for other grades, are listed in Table 1. They may be used with the factor *I* discussed under "Land Slope." The 1 to 4-in variable and 4-in uniform grades are the ones most commonly used in Missouri. With terraces of a uniform size it would seem that short terraces could utilize a flatter grade and thus reduce soil movement out of the end of the channel. Practical limitations of construction and farming have shown that grades of less than 2 in are nearly always impractical.

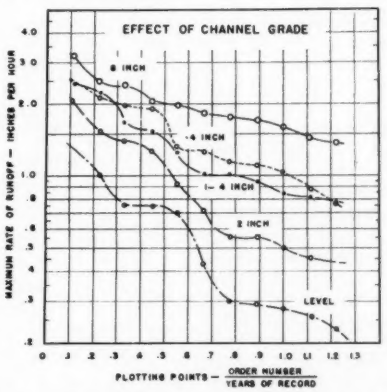

Fig. 1 The effect of channel grade on the maximum rates of runoff during a 9-yr period from terraces on a Shelby loam field of 11 per cent slope

Length. A variation in terrace length is, like a variation in spacing, directly reflected in a change in the drainage area. Thus the effect on the discharge rate resulting from a change in length would be accounted for in a runoff equation by the drainage area factor. As discussed under terrace spacing, the drainage area factor is the area in acres to some power a little less than unity. Evaluation of this exponent was made by use of the terrace length study data, which consisted of 5 yr of runoff records from two terraces, one 1375 ft long and the other 2450 ft. Land slope and soil depth were nearly equal for the two terraces, although the small differences that did exist were such as to cause a reduced rate and amount of runoff from the short terrace.

There were fourteen storms during the period of study which produced, on the long terrace, 0.50 in or more of runoff with maximum rates of 0.25 iph (inch per hour) or more. Ratios of the maximum rates of runoff (short divided by long) were correlated as a function of the amount ratios. The resulting equation was

$$R_R = 1.05\, R_A^{1.05} \qquad [1]$$

in which R_R is the rate ratio and R_A the amount ratio. When total runoff was equal for the two terraces, which should have been the case had no differences existed between the terraces or their drainage areas except that due to the difference in length, the rate ratio was equal to 1.05. This means that the rate of runoff in inches per hour was 5 per cent greater from the short than from the long terrace. The value of the exponent of area in acres may be calculated by use of this ratio and the drainage areas of the two terraces. It was found to equal 0.91 and as such was used to adjust the measured rates of runoff for terraces of different length to a uniform basis, so that the effect of land slope on rate of runoff could be evaluated.

Land Slope. Runoff records were available for either a 9 or 10-yr period for 17 individual terraces. The land slope for the drainage areas of

TABLE 1 EFFECT OF CHANNEL GRADE ON RELATIVE RATE OF RUNOFF FOR A FREQUENCY OF ONCE IN TEN YEARS

Grade of channel	Relative rate of runoff per unit area
0	0.52
1	0.71*
2	0.83
3	0.93*
4	1.00
5	1.07*
6	1.13*
8	1.28

*Interpolated

This paper was presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1947, as a contribution of the Soil and Water Division. Missouri College Agriculture Journal Series Paper No. 1081, a contribution of the Soil Conservation Service (Research), USDA, and the Missouri Agricultural Experiment Station.

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*Superscript numbers refer to appended references.

TABLE 2. THE EFFECT OF CROPPING SYSTEM ON MAXIMUM RATE OF RUNOFF PER ONE-ACRE AREA

Rotation	Terrace	I*, iph
Corn—oats and sweet clover	1H	2.72
	2H	3.87
	Average	3.30
Corn—soybeans — wheat — meadow	3H	3.59
	4H	3.20
	5H	3.32
	6H	3.02
	Average	3.28
Corn—oats—meadow	7C	2.42
	5N	2.98
	H†	3.87
	Average	3.09

*Measured rates adjusted to a 10 per cent slope by use of equation [5].

†To complete the rotation cycle the required data were secured from the appropriate H terraces.

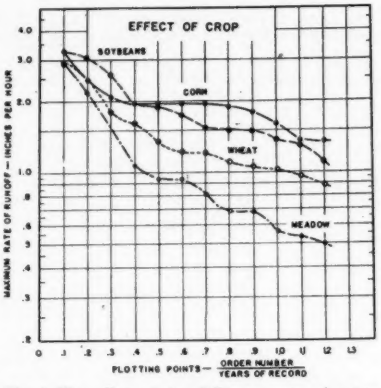

Fig. 2 The effect of the different crops of a 4-yr rotation of corn-soybeans-wheat-meadow on the maximum rates of runoff during a 10-yr period from terraces on a Shelby loam field of 10 per cent slope

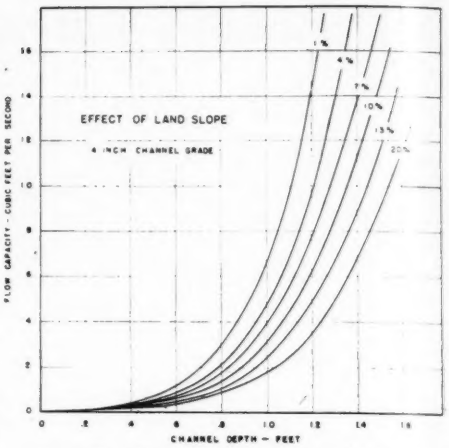

Fig. 3 The effect of land slope on the channel flow capacity of terraces when in meadow

these terraces varied from 6.3 to 13.9 per cent. The 10-yr frequency runoff rates from fourteen of these terraces having a minimum grade variation were determined by plotting the yearly maximum rates on semilogarithmetic paper. As all terraces were not the same length or spacing, the rates of runoff were adjusted to a uniform basis by the equation

$$I = I_1 A^{0.09} \qquad [2]$$

in which I is the rate of runoff in inches per hour for a terrace with a one-acre drainage area, I_1 the 10-yr frequency rate of runoff in inches per hour as measured for the terrace, and A the drainage area in acres. Equation [2] was derived from the runoff equations

$$Q = 1.008 I A^{0.91} \qquad [3]$$

and

$$Q = 1.008 I_1 A \qquad [4]$$

These latter two equations were used with equation [1] to evaluate the exponent of A, 0.91 as discussed under terrace length.

The factor I is affected by land slope, soil depth, and cropping, as well as rainfall. Available data make possible evaluation of the land slope factor in a fairly satisfactory manner with rainfall held constant and the cropping and soil depth factors as nearly constant as possible. By grouping and averaging the data, values of I were secured for four slope groups ranging from 6.8 to 13.2 per cent. Plotting of these points on logarithmic paper indicated that the relationship was of the type

$$I = a + bS^n \qquad [5]$$

in which S is land slope in per cent and a is the rate of runoff from a terrace of one-acre drainage area on a zero per cent slope. The constants b and n determine the amount of change in runoff rate per unit of land slope. The calculated values of the constants were: $a = 2.34$, $b = 0.0051$, and $n = 2.06$. Reducing n to 2.0 and increasing b to 0.00595 results in an equation that is easier to use without changing the result beyond the accuracy of the original data.

The effect of land slope determined by equation [5] is relatively small except for the steeper slopes. A change from 4 to 8 per cent slope results in the runoff rate increasing a little more than 11 per cent, whereas a change from an 8 per cent to a 16 per cent slope results in an increase of 42 per cent. Artificial rain studies on a small indoor plot by Woodruff[2] have shown that rate of runoff is constant for all slopes when the applied rate of rainfall is constant throughout the period of concentration for each slope. Steepening the slope decreased the period of concentration and thus shortened the time required for the runoff to attain its terminal rate. With natural rainfall, particularly with terraces, the most intense rainfall will seldom be maintained throughout the period of concentration. Thus a difference in rate of runoff could be expected for different land slopes. The difference, however, should decrease as the frequency of occurrence decreases—that is, less for a 10-yr runoff than for a 2-yr runoff.

Cropping. The probability of a rainstorm producing a runoff rate of the same frequency as that of the rain is remote. It could occur only if soil and cover condition remained constant throughout the year. Thus there should be a relationship between rate of runoff of a given frequency and the cropping system, the rate increasing with an increase in the per cent of time that the cropping system allows the soil to be in a vulnerable condition for high runoff. This is indicated by the rotation averages in Table 2. The maximum rate for any crop is the 3.87 iph shown for the corn-oats and sweet clover rotation on terrace 2H. This runoff was caused by a rain having a 30-yr frequency which occurred at oat seeding time, the most vulnerable period in the rotation for high runoff rates. Plotting of the yearly maximum rates of runoff against frequency for terrace 2H indicates that this rate is probably close to a 25-yr instead of a 10-yr frequency. This was the only terrace in oats at that time. Crops such as corn and soybeans generally allow higher rates of runoff than wheat or meadow, although the difference is much less for a 10-yr frequency runoff than a 2-yr runoff. This is illustrated in Fig. 2.

An Equation for Runoff. The constants of equation [5] were evaluated by the use of rates secured under a corn-oats-meadow rotation with only one crop of the rotation represented during a year. Had all crops of the rotation been represented each year, the value of the constant would have been larger as indicated by the rotation average in Table 2. By increasing these constants 12 per cent, they will give a calculated value of I equal to the highest rotation average, or that for the corn-oats and sweet clover rotation of Table 2. They are of sufficient magnitude without this correction to estimate satisfactorily the probable runoff for individual terraces when in a meadow crop as indicated by Fig. 2. For purposes of estimating flow for a terraced field for design of an outlet

TABLE 3. RETARDANCE VALUES FOR A TERRACE CHANNEL WHEN PLANTED TO CORN AND WHEN IN MEADOW

4-in per 100-ft grade

Hydraulic radius	Corn* 6 in high	Timothy meadow*	Bluegrass†	6 in grade Bluegrass†
0.20	0.050	0.33	0.43	0.12
.30	.023	.28	.39	.08
.40	.020	.22	.35	.04
.50	.020	.175	.31	.08
.60	.020	.133	.24	.065
.70	.020	.099	.135	.092
.80	.020	.076	.085	.062
.90	.020	.063	.063	.048
1.00	.020	.054	.054	.040

*From terrace channel flow study at Bethany[5]

†From terrace outlet channel tests at McCredie[4]

TABLE 4 FLOW CAPACITY AND SIZE REQUIRED FOR TERRACE CHANNELS WITH A 4-IN GRADE TO CARRY A 10-YR FREQUENCY RUNOFF WITH THE TERRACE IN MEADOW

Land slope, %	Horizontal spacing, ft	Terrace length, ft	Flow capacity, cfs	Cross section area, sq ft	Depth, ft	Flow top width, ft	Recommended height, in*
		500	3.4	9.6	.83	18	14
1	130	1000	6.4	12.8	.99	20	16
		1500	9.3	14.1	1.08	21	17
		500	2.4	7.0	.83	14	14
4	85	1000	4.5	9.5	.99	16	16
		1500	6.5	11.0	1.08	18	17
		500	2.2	6.3	.85	12	15
7	70	1000	4.1	8.5	1.02	14	17
		1500	5.9	10.0	1.12	15	18
		500	2.1	5.9	.90	10.5	16
10	60	1000	4.0	8.0	1.07	12	18
		1500	5.7	9.3	1.17	13	19
		500	2.2	5.5	.97	9.5	17
13	54	1000	4.1	7.4	1.14	11	19
		1500	5.9	8.8	1.26	11.5	20
		500	3.1	5.3	1.17	8	19
20	54	1000	5.8	7.4	1.35	9	21
		1500	8.4	8.6	1.47	10	23

*This is the height after seedbed preparation for corn, or settled height after construction. Elevation readings taken at Bethany indicate this height will decrease about 4 in by cultural operations and channel deposition between corn cultivation and establishment of meadow.

the higher values appear more satisfactory. In this form the equation for runoff in cubic feet per second becomes

$$Q = A^{.91}(2.64 + 0.0067S^2) \qquad [6]$$

DETERMINATION OF REQUIRED CHANNEL SIZE

To determine the ridge height and channel area for the required flow in a terrace channel, discharge curves were prepared for terraces on land slopes of 1, 4, 7, 10, 13, and 20 per cent. The channel areas were based on Missouri cross-section recommendations, with some modification for changes that would take place under farming as shown by cross-section readings secured from the Bethany Station terraces.

Channel Retardance. With channel area and hydraulic radius known for different stages of flow, retardance values are required for calculation of stage discharge curves. Data secured from tests at Bethany[3] and McCredie[4] provided retardance values for this purpose. They are shown in Table 3. Retardance values for meadow which were measured in a terrace channel on a 4-in grade at Bethany are those recommended for calculating channel flow. The higher values for bluegrass secured from the McCredie outlet tests represent values for a more dense sod than secured in the bottom of a terrace channel, where the grass is generally thin due to a wet soil condition.

Stage-Flow Relationship for Different Slopes. Two extreme conditions of channel flow existed (a) when the terrace was planted to corn and (b) when the terrace was in meadow. With corn the retardance was sufficiently low that flow depths of 0.5 to 0.7 ft were required for a 10-yr frequency runoff (a 1000-ft terrace on a 4-in grade). The capacity of the channel was most fully utilized only when in meadow, even though the runoff rate was about 11 per cent less than for corn. The resulting discharge curves calculated by use of the Manning formula and the retardance values of Table 3 for meadow are shown in Fig. 3.

Required Channel Capacity, Area, and Depth. The required channel size will vary with terrace length and land slope. The necessary flow capacity for lengths of 500, 1000, and 1500 ft, with a channel grade of 4 in, were calculated by use of equation [6] but with the slope constants recommended for meadow. They (flow capacities) are shown in Table 4 with corresponding channel size, and with the recommended

Table 5—Terrace outlet size table for the Shelby loam soil region of Missouri, Iowa, Nebraska, and Kansas

Slope		4	6	8	10	12	14	16	18	20	22	24	26	30	34	38	42	46	50
1	Q	9	14	18	22	25	29	33	37	40	44	48	51	58	66	73	79	86	93
	D	.79	.84	.88	.91	.94	.97	1.01	1.04	1.07	1.10	1.14	1.16	1.21	1.27	1.32	1.36	1.39	1.43
	W	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
2	Q	9	14	18	22	26	29	33	37	41	44	48	52	59	66	73	80	87	94
	D	.60	.65	.70	.74	.77	.80	.83	.87	.89	.91	.93	.95	1.02	.96	.92	.89	.87	.86
	W	8	8	8	8	8	8	8	8	8	8	8	8	8	10	12	14	16	18
3	Q	10	14	18	22	26	30	34	38	41	45	49	52	60	67	74	81	88	95
	D	.53	.57	.60	.64	.68	.71	.74	.77	.79	.80	.77	.76	.73	.72	.70	.69	.68	.68
	W	8	8	8	8	8	8	8	8	8	8	10	11	13	16	18	21	23	26
4	Q	10	14	18	22	26	30	34	38	42	46	50	53	61	68	75	83	90	97
	D	.49	.53	.56	.59	.62	.65	.68	.69	.67	.65	.64	.63	.61	.60	.60	.59	.58	.58
	W	8	8	8	8	8	8	8	8	10	11	13	14	17	20	23	26	28	31
5	Q	10	14	19	23	27	31	35	39	43	47	51	55	62	70	77	84	92	99
	D	.45	.49	.53	.56	.59	.62	.62	.60	.59	.57	.56	.55	.55	.54	.53	.53	.52	.52
	W	8	8	8	8	8	8	9	10	12	14	16	17	21	24	27	30	33	36
6	Q	10	15	19	23	28	32	36	40	44	48	52	56	64	71	79	86	94	101
	D	.42	.47	.51	.54	.57	.54	.53	.52	.51	.50	.50	.49	.49	.48	.48	.48	.48	.48
	W	8	8	8	8	8	10	11	13	15	17	19	21	24	28	31	35	38	42
8	Q	11	16	20	25	30	34	38	43	47	51	55	60	68	76	84	92		
	D	.39	.44	.47	.50	.47	.46	.45	.44	.44	.43	.43	.43	.43	.42	.42	.42		
	W	8	8	8	8	11	13	15	17	19	21	23	26	30	34	38	42		
10	Q	12	17	22	27	32	37	41	46	51	55	60	64	73	82				
	D	.38	.42	.44	.42	.40	.39	.39	.39	.39	.38	.38	.38	.38	.38				
	W	8	8	9	12	14	17	19	22	25	27	30	32	37	42				
12	Q	13	18	24	29	35	40	45	50	55	60	65	70	80					
	D	.36	.39	.39	.38	.37	.37	.37	.36	.36	.36	.36	.36	.36					
	W	8	8	10	13	17	20	23	26	29	32	35	38	44					
14	Q	14	20	26	32	38	44	49	55	60	66	71							
	D	.35	.37	.35	.34	.34	.33	.33	.33	.33	.33	.33							
	W	8	10	14	17	21	25	28	32	35	38	42							
16	Q	15	22	29	35	42	48	54	61	67									
	D	.35	.34	.33	.32	.32	.32	.31	.31	.31									
	W	8	12	16	20	25	29	33	38	42									

Q = Runoff in c.f.s. D = Depth of flow in feet. (Add 0.5 foot for settled construction depth) W = Bottom width of channel in feet.
Velocities to right of heavy line are 5 feet per second. Flows on left of heavy line are not sufficient to produce a 5-foot-per-second velocity in an 8 foot wide channel.
Trapezoidal cross section with 4 on 1 side slopes.

EDITOR'S NOTE: The top horizontal row of figures in this table represent acres.

ridge height in inches. This height is 5 in greater than the flow depth for slopes of 7 per cent and greater, as cross-section elevation readings secured at Bethany at different times during the rotation cycle showed that the ridge height would decrease about 4 in on a 13 per cent slope between corn planting and establishment of the meadow crop two years later. On the slopes of 1 and 4 per cent only 4 in were added to the required flow depth. With channel grades more than 4 in per 100 ft somewhat less height would be required. On the extremely steep land slopes terrace length should be limited to 1000 ft or less to reduce the required ridge height to practical limits.

DETERMINING OUTLET DIMENSIONS

The first step in selection of the outlet size required for a terraced field is to determine the probable runoff for the desired frequency. A 10-yr frequency is probably the most practical for this use. A table of expected runoff rates for different areas and land slopes was prepared by use of equation [6]. An outlet size table for bluegrass, listing the width and flow depth, required on different land slopes for different runoff rates up to about 160 cfs (cubic feet per second) was next prepared from the McCredie channel test data. These two tables would provide the farm planner sufficient information to design correctly nearly any outlet. Some interpolation between the tabulated figures would be necessary.

A simpler arrangement would be to prepare one table giving the outlet size required for a given area and land slope. With such a table the average land slope of the field is assumed to equal the steepest part of the outlet. This introduces an error which in practically all cases is on the side of safety as the outlet size selected is generally larger than one determined by the use of the two tables. This is due to the fact that the average land slope is nearly always less than the steepest section of the outlet. Thus the 10-yr frequency runoff used in preparation of Table 5 would produce a velocity somewhat less than the 5-fps velocity used in preparation of the table. Simplification of the process, however, may be of more value than the small increased cost of the larger outlet. Table 5 is of this type, but with the runoff rates included. It is applicable to the Shelby loam region of Missouri, Iowa, Kansas, and Nebraska[3].

The design velocity of 5 fps used in the table is considered safe for bluegrass on Shelby surface soil of 6-in or greater depth where ordinarily good soil treatment and care are exercised in establishment and maintenance of the outlet. With shallower surface soil a design velocity of 4 fps would be safer and for the most unfavorable outlet conditions in severely eroded locations a velocity of only 3 fps should be used. Such tables can be readily prepared from data previously published[4].

A trapezoidal cross-section outlet with side slopes of 4 on 1 was used for the table. Settled construction depth should be about 0.5 ft greater than the flow depth shown in the table.

If the average land slope of a field differed materially from the steepest section of the outlet, the correct size of the outlet could be selected as follows:

Assume a drainage area of 26 acres on an average slope of 8 per cent but with a maximum outlet slope of 12 per cent. If the outlet were selected for a 12 per cent slope and 26 acres, it would be 38 ft wide and would have a flow depth of 0.36 ft. If the discharge of 60 cfs for a 26-acre field of 8 per cent average slope were used, the size selected would be 32 ft wide with a 0.36-ft flow depth. These dimensions were secured by moving to the left on the 12 per cent slope line from the 26-acre area column until a runoff rate of 60 cfs was found. (In this case it was in the 22-acre column for the 12 per cent slope line.)

REFERENCES

1 Hobbs, Harold W. Rates of runoff in the Coastal Plains of New Jersey, Delaware, and Maryland. USDA, SCS-TP-60. July, 1946.

2 Woodruff, C. M. Erosion in relation to rainfall, crop cover and slope on a greenhouse plot. To be published in Proc. Soil Sci. Soc. of Amer., vol. 12, 1948.

3 Smith, D. D., et. al. Investigations in erosion control and reclamation of eroded Shelby and related soils at the Conservation Experiment Station, Bethany, Mo., 1930-42. USDA Tech. Bul. 883, 1945.

4 Smith, D. D. Bluegrass terrace outlet channel design. AGRICULTURAL ENGINEERING, pp. 125-130, March, 1946.

5 Clark, Marion and Wooley, J. C. Terraces for erosion control. Mo. Agr. Exp. Sta. Bul. 507, 1947.

Supplementary Irrigation

FROM the data, two very important general suggestions can be given. First, in the late spring, summer, and fall, it is possible to supply more water than the crop plants can use, with the results that yields will be lower than can be expected, from the best irrigation practice. Second, irrigation is most effective during those months when the loss of water from the soil and through the plants is greatest. During the late spring of 1946, with a rainfall of 1.18 in per week, one inch of irrigation water a week seemed to be about the right amount to apply.—*From a contribution by B. S. Pickett in the Annual Report of Research and Investigational Activties, College of Agriculture, University of Georgia, for the fiscal year ending June 30, 1948.*

This picture shows part of the group that attended the organization meeting, April 29 and 30 and May 1 at Kansas City, Mo., of the new Mid-Central Section of the American Society of Agricultural Engineers comprising the states of Kansas, Nebraska, and Missouri

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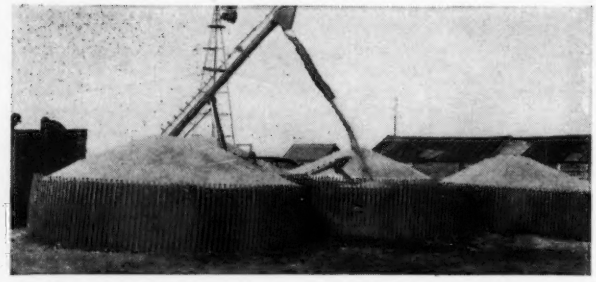

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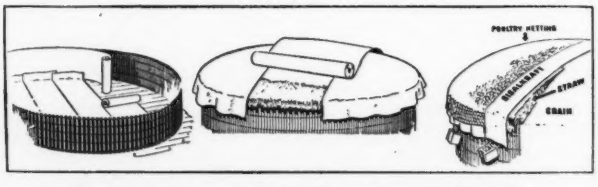

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Agricultural Engineering on WGY Farm Forum

GEO. A. RIETZ, president of the American Society of Agricultural Engineers, explained agricultural engineers and agricultural engineering to the radio audience of the WGY (Schenectady) Farm Forum program, Friday evening, May 21.

In picturing agricultural engineers and their work for an audience made up largely of farmers and others who are not engineers, Mr. Rietz drew some comparisons which may prove useful to other agricultural engineers in interpreting their work. He said, in part, "An agricultural engineer is a man trained in engineering who is using that engineering 'know-how' to solve some of the production, processing and other types of operations on American farms. We look upon agriculture as an industry as great as any we have in America today.

"The American Society of Agricultural Engineers is 41 years old. Like the other technical engineering groups that you commonly hear of, the Society is made up of the technically trained agricultural engineers, and its only purpose is to make this type of engineering more productive and raise the standards of training and performance.

"One way to answer the question 'For whom do the agricultural engineers work?' is to say that agricultural engineers are really working for farm people.

"You will find among agricultural engineers many who have specialized in electrical engineering, some who specialized in mechanical engineering, and others who have majored in civil or chemical engineering. They are highly trained engineers but tagged as agricultural engineers because they are applying their engineering training to the problems of agriculture. Particularly before an audience of farm people, I would like to make it clear that we agricultural engineers are proud of the American farm families with whom and for whom we work. Each of us is on the job primarily because he feels he can accomplish more on it and it is a job more to his liking than some other he might have selected. Like engineers in the mining, steel, transportation, and other industries, we happened to select agriculture because that is to our liking.

"During the past 35 years, the production per farm worker in this country has increased 98 per cent. During that same period, the output per industrial worker has increased 92 per cent. So you can see that during the past 35 years, agriculture has more than kept up with the other industries in this country. Might I make the natural and proper additional remark that agricultural engineers do not claim sole responsibility for this outstanding accomplishment. There are others working on the problems of agriculture and they have developed better producing seeds, feed, fertilizers, insecticides, and farm animals, that have also contributed mightily.

"Although we are proud, we are not satisfied. In 1946, the bill farmers in this country paid to operate their farms was 18 billion dollars. We know that this operating expense can be reduced materially by making farmers directors of power rather than generators of power in handling many more of their farming operations. The point is that, for example, a one-horsepower electric motor operating most any kind of farm machine will do the same mechanical work in one hour that a husky hired man can do in an eight-hour day. The motor will do that work at a cost of only three or four cents, so farm workers like workers in all industry should look upon power as an ally which he directs to produce more in a shorter time and to further reduce the drudgery of his job, as well as the cost of accomplishing it.

"Speaking in very specific terms and just for a period of the past ten years, here in New York State, dairymen have cut the man-hours required to produce milk and take care of their dairy herds by about 30 million hours a year, primarily due to mechanization. Dairymen in Vermont reduced their working time by 5 per cent even though their production was increased by 11 per cent. Engineers have the reputation of not being satisfied with any method or piece of equipment we have. They are constantly looking for a better way. For example, the USDA estimates that enough protein is lost from hay each year to feed another 7,500,000 head of livestock. This loss occurs because of field-curing methods. The new development of curing hay in the barn will cut much of that loss, and, incidentally, barn hay curing is being adopted by farmers throughout the country quite generally. You will find the several thousand agricultural engineers in this country constantly examining present farm equipment of all kinds and carefully scrutinizing the arrangement of farm buildings, tillage, and other farm practices. It is through such diligence and careful searching and applying engineering knowledge to the specific problems that we find constant improvement in existing methods and equipment and the development of new and better equipment and methods. That is the American system and it is the one that does pay off."

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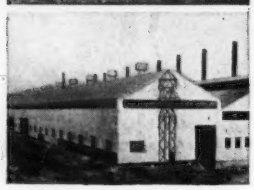

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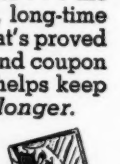

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NEWS SECTION

A.S.A.E. Meetings Calendar

June 21 to 24 — ANNUAL MEETING, Multnomah Hotel, Portland, Oregon.

September 8-10 — NORTH ATLANTIC SECTION, Ontario Agricultural College, Guelph, Ont., Canada.

October 21 and 22 — PACIFIC NORTHWEST SECTION, Columbia Gorge Hotel, Hood River, Ore.

December 13-15 — WINTER MEETING, Stevens Hotel, Chicago.

Virginia Section Elects Kite

NEARLY 100 members, friends, and students attended the third annual meeting of the Virginia Section of the American Society of Agricultural Engineers held at Roanoke, May 14 and 15. At this meeting the Section members elected as the chairman for the 1948-49 year, G. D. Kite, associate extension agricultural engineer, Virginia Polytechnic Institute. It also elected three vice-chairmen: P. B. Potter, agricultural engineer, and J. H. Lillard, associate agricultural engineer, Virginia Agricultural Experiment Station, and W. J. Gillespie, Jr., assistant district manager, Appalachian Electric Power Co. J. E. Collins, assistant extension agricultural engineer, V.P.I., was elected secretary-treasurer of the Section.

Three outstanding addresses featured the program of the first session of the meeting on the afternoon of May 14 — one by R. H. Driftmier, head of the agricultural engineering department, University of Georgia, and a past-president of A.S.A.E., on co-ordinating agricultural engineering effort; another on rural industries in Virginia by Raymond V. Long, director of the Virginia State Planning Board, and the third on rural electrification in a co-ordinated agricultural engineering program by G. E. Henderson, head of the agricultural engineering section, Tennessee Valley Authority.

At the Section dinner held on the evening of May 14, M. C. Via, vice-president of the First National Exchange Bank of Roanoke, addressed the group on the subject of sound farm credit for production improvement and conservation.

The concluding session of the meeting, on the forenoon of May 15, included three papers. O. R. Randolph, consulting engineer, at Charlottesville, Va., spoke on long-range flood control. He was followed by D. C. Heitshu, Chief engineer, John Deere Harvester Works, of Deere & Co., who discussed new developments in farm power equipment. The concluding paper by M. V. Englebach, manager of field engineering, The Ruberoid Co., was on the subject of farm structures in a co-ordinated agricultural engineering program.

Local newspapers were most generous in the amount of space given to the program of the meeting, which is an indication that the Virginia Section is doing an excellent job in selling agricultural engineering in the state.

Michigan Ag Engineers Have Gala Day

TO COINCIDE with the ceremony dedicating the new agricultural engineering building on the Michigan State College campus, the Michigan Area Section of the American Society of Agricultural Engineers held its annual meeting May 6 at East Lansing.

The forenoon was devoted to the Section program which featured two talks on the subject of farm structures, one by B. G. Perkins of the Doane Agricultural Service on farm structures as a tool, the other by E. F. Boyle of the Johns-Manville Corp. presenting a number of practical examples of remodeled farm structures.

These talks were followed by a short business session, which included a short speech by retiring Section Chairman H. J. Gallagher, the announcement of the results of the mail ballot of new officers of the Section, and the installation of these officers. The new Section officers are as follows: Chairman, Dan W. Guy, agricultural engineer, Ethyl Corp.; vice-chairman, M. L. Bailey, assistant professor of agricultural engineering, Michigan State College; J. C. Cahill, district co-ordinator, Detroit Edison Co., and D. A. Milligan, director of production, Harry Ferguson, Inc. F. W. Peikert, agricultural engineering department, Michigan State College, was re-elected secretary-treasurer. The new Nominating Committee of the Section consists of A. F. Farrall (chairman), A. H. Glaves, and Chris Nyberg.

Afternoon and evening programs were devoted exclusively to the dedication of the new agricultural engineering building. The afternoon program included two addresses, one by H. B. Dirks, dean of engineering, Michigan State College, on engineering and agriculture combining forces, and the other by President Geo. A. Rietz of the American Society of Agricultural Engineers on the service which agricultural engineers are rendering to agriculture. In addition, A. W. Farrall, head of the department of agricultural engineering at M.S.C., reviewed the teaching, research, and extension program in agri- (*Continued on page 272*)

Millions of people changed our name

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Several years after the company started operations in 1900, it adopted the trademark "ARMCO" for its special grades of steel. The ARMCO trademark —composed of the first letter in each word of the company name—has been widely advertised and appears on all the company's products. Many ARMCO customers identify their use of these special-purpose steels with this familiar trademark.

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THE FAMILIAR ARMCO TRIANGLE IDENTIFIES SPECIAL-PURPOSE STEELS THAT HELP MANUFACTURERS MAKE MORE ATTRACTIVE, MORE USEFUL, LONGER-LASTING PRODUCTS

you Can take it with you...

AN Indian papoose has plenty of portability. His mother just packs him along. Just like today's farmer can easily carry his saw wherever he wants it.

But it wasn't always that easy. Old-time stationary saws had their limits. Wood had to be carried to the saw. And then carted where the farmer wanted it. That added up to a lot of wasted time and effort.

Seeing this, agricultural engineers developed a combination saw, using tractor to move and power it. On the tractor the saw goes anywhere. It cuts logs right in the woods. Then back at the farm a few simple bolt adjustments quickly change it to a stationary saw.

Simple? Sure. But it took men who could recognize a farm problem . . . and know what to do about it . . . to make the combination saw a reality. Another triumph for agricultural engineering applied to farm machinery.

NEW HOLLAND MACHINE COMPANY

NEW HOLLAND, PENNSYLVANIA

NEW HOLLAND

FARM ENGINEERED MACHINERY FOR BETTER FARMING

NEWS SECTION

(*Continued from page 270*)

cultural engineering and introduced the members of his staff. This was followed by a guided tour of the new building.

The dedication ceremonies were climaxed by a banquet in the evening at which E. L. Anthony, dean of agriculture, M.S.C., presided as chairman. The dinner was attended by about 300 persons, including many visiting agricultural engineers, and the group was welcomed to the campus by President John A. Hannah of the College. The response to President Hannah's welcome was made by H. J. Gallagher, retiring chairman of the Michigan Area Section of the A.S.A.E. This was followed by a talk by J. A. Porter of the Detroit Agricultural-Industrial Foundation on agriculture and industry working together, and an address by Arthur W. Turner, assistant chief, USDA Bureau of Plant Industry, Soils, and Agricultural Engineering, on looking forward in agriculture.

The new agricultural engineering building at Michigan State College is believed to be the largest of its kind in the country and contains over 60,000 square feet of floor space. The agricultural engineering staff includes 33 persons together with 8 graduate student assistants and fellows. During the past quarter, 1200 students were enrolled in the agricultural engineering classes. Of these 80 are four-year technical agricultural engineering majors, 35 are four-year farm engineering majors, 26 are five-quarter service and sales trainees, and 21 are graduate majors in agricultural engineering.

Panama Decorates Earle K. Rambo

THE Panamanian Government recently decorated Earle K. Rambo, acting chief of the U. S. Agricultural Mission to the Republic of Panama, with the order of Vasco Nunez de Balboa in the grade of "Commendador" in recognition of the work he has done while serving as an adviser to the Panamanian Ministry of Agriculture.

Mr. Rambo received Panama's highest award shortly before returning to Little Rock, Ark., where he will resume his duties as extension agricultural engineer of the Agricultural Extension Service of the University of Arkansas.

He left Panama on May 1, accompanied by his wife and three sons, for Washington for consultations with U. S. Department of Agriculture officials. Mr. Rambo was granted a leave of absence in June, 1947, by the University of Arkansas, to be assigned to Panama by the Office of Foreign Agricultural Relations of the U. S. Department of Agriculture as an adviser. He was later promoted to acting chief of the mission.

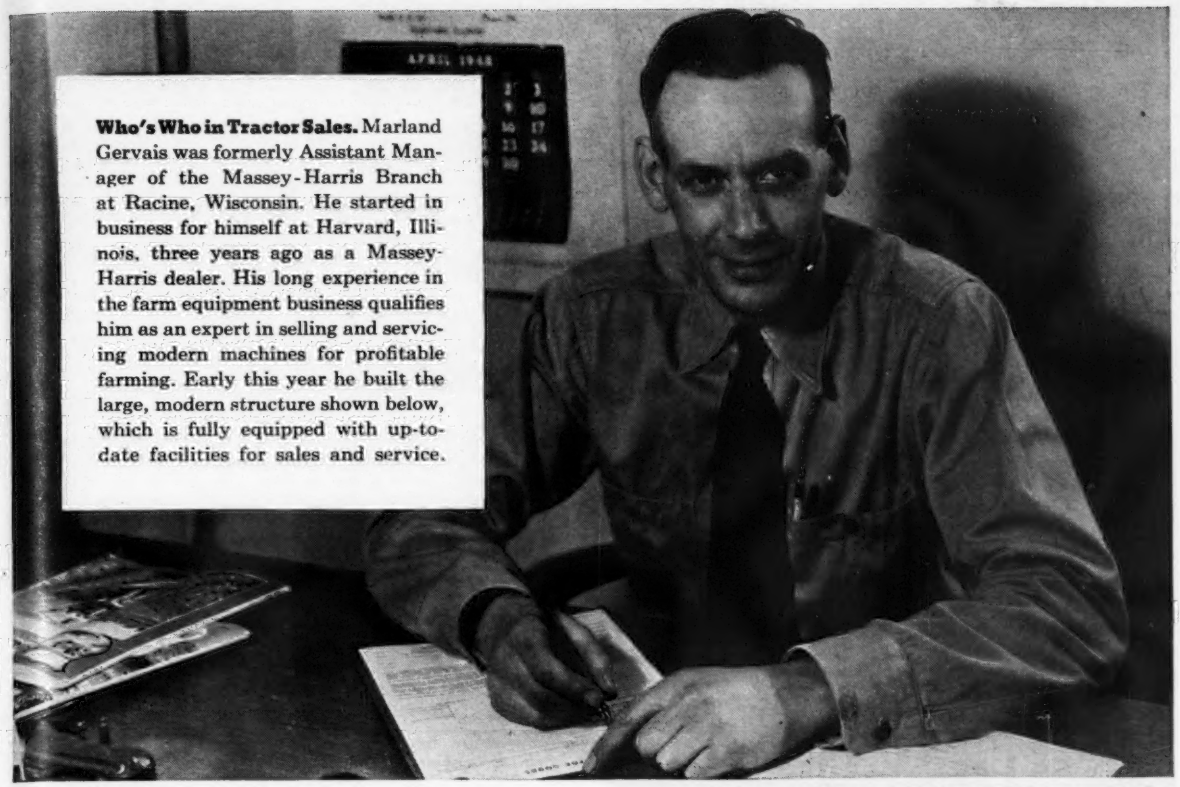
The decoration was presented by the Minister of Agriculture, Prof. Guillermo Mendez Pereira, at the Foreign Office. Present at the ceremony were Mrs. Rambo, high Panamanian officials and officers of the American Embassy and the United States Army stationed in the Canal Zone. (*News continued on page 274*)

Earle K. Rambo is shown in this picture receiving congratulations from Panamanian Minister of Agriculture Guillermo Mendez Pereira after having been decorated with the Order of Vasco Nunez de Balboa in the Foreign Office at Panama City. Mrs. Rambo is at the left

New Literature

FIRE AND TOXIC GAS HAZARDS OF PAINT FILMS, by Mark W. Westgate. Circular 724, Scientific Section, National Paint, Varnish, and Lacquer Assn., Inc. (Washington, D.C.)

An 8-page, 6 x 9-inch circular presenting the need of further information on the subject, and a test procedure to be used in obtaining it. Results of individual tests are to be presented in subsequent circulars. A copy will be furnished to any A.S.A.E. member on request.



Who's Who in Tractor Sales. Marland Gervais was formerly Assistant Manager of the Massey-Harris Branch at Racine, Wisconsin. He started in business for himself at Harvard, Illinois, three years ago as a Massey-Harris dealer. His long experience in the farm equipment business qualifies him as an expert in selling and servicing modern machines for profitable farming. Early this year he built the large, modern structure shown below, which is fully equipped with up-to-date facilities for sales and service.

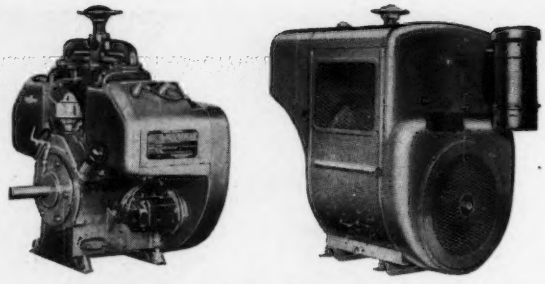
"We are building our business on high compression tractors and combines,"

says Marland Gervais, Massey-Harris dealer at Harvard, Illinois

"After starting in business here, it didn't take us long to recognize the important sales advantage we have in selling high compression. Our tractor customers are sold on the quicker starting, faster warm-up and better idling they get from gasoline tractors. And those same advantages," Mr. Gervais adds, "are just as important to our self-propelled combine owners.

"Both tractor and combine owners like the *extra power, maximum economy* and *smooth performance* delivered by a high compression engine, designed to take full advantage of gasoline. It all adds up to more work per hour . . . more acres per day—whether it's a tractor job or harvesting grain with a self-propelled combine. Believe me, we're building our business on high compression tractors and combines."

Mr. Gervais is right when he says farmers are sold on high compression. Eight out of ten tractor owners today prefer gasoline and about eighty per cent of tractors being manufactured today have high compression engines which give the farmer maximum power from his favorite fuel. You can be sure that when you recommend high compression, you are helping the farmer get the kind of tractor power he is looking for. *Ethyl Corporation.*



Let this 20-Horse Team

Handle Your Heavy-Duty Power Jobs

Turning up 20.5 hp. at 2200 R.P.M. the Model VE-4 WISCONSIN Standard Air-Cooled Engine (left) and the Model VE-4 Complete Power Unit (right), can always be depended upon for continuous, heavy-duty operation in any kind of service, on any kind of equipment within their power range.

Positive, trouble-free AIR-COOLING; dynamically balanced crankshaft mounted on tapered roller bearings, *front* and *rear;* high tension magneto with impulse coupling for quick, easy starting in any weather . . . these are features that you can bank on for top performance.

Specify Wisconsin Air-Cooled Engines for YOUR equipment . . . for most hp.-hours of service, at the lowest overall cost.

Most H.P. per pound

WISCONSIN MOTOR Corporation

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World's Largest Builders of Heavy-Duty Air-Cooled Engines

EWC WHEELS

Designed to do the Job

For more than fifty years we have built dependable steel wheels for movable equipment . . . agricultural and industrial.

You can rely on EWC engineers to recommend the correct wheels for your unit. This is particularly valuable when new machines or new models are being considered.

If one of our standard wheels is not the most efficient, we can design and manufacture special wheels.

Write for our catalog

ELECTRIC WHEEL CO., Quincy, Illinois

NEWS SECTION

(*Continued from Page 272*)

Professor Davenport Honored

THE Georgia Student Branch of the American Society of Agricultural Engineers was host to the Clemson, (S. C.) Branch on Friday night, May 21, 1948, at a delightful banquet on the University of Georgia south campus at Athens. Approximately fifty persons from Clemson Agricultural College and seventy from the University of Georgia attended. The banquet was in honor of Professor Uriah H. Davenport's fifty years of service as teacher at the University of Georgia.

Principal speakers of the occasion were R. H. Driftmier, professor and head of the agricultural engineering department at Georgia; Geo. B. Nutt, head of the agricultural engineering department at Clemson; Paul W. Chapman, dean of the college of agriculture at Georgia, and H. D. Whittemore, senior student (at Georgia) in agricultural engineering and president of the National Council of A.S.A.E. Student Branches. Dean Chapman paid tribute to the unique and splendid service rendered by "Fess" Davenport during his fifty years of teaching and acclaimed him the "father of agricultural engineering" at the University of Georgia.

Since June 15, 1898, when he graduated with a bachelor of science degree, Professor Davenport has taught physics, astronomy, electrical, civil, and agricultural engineering. Since joining the agricultural engineering staff in 1932, he has taught hydraulics, mechanics, strength of materials; but perhaps he is best known as the man who teaches, dc and ac electricity. He is a member of Phi Beta Kappa, Phi Kappa Phi, Phi Delta Theta, the American Institute of Electrical Engineers, and the American Society of Agricultural Engineers.

During the banquet Professor W. E. Hudson, on behalf of the Georgia Agricultural Engineering Club, awarded an honor key to William G. Reeves, Jr., Cartersville, Ga. Reeves, one-time president of the National Council of Student Branches of A.S.A.E., has served as president of the Georgia Agricultural Engineering Club, editor of the Georgia "Agricultural Engineer," a member of the editorial staff of the "Georgia Agriculturist," and has been an active member of the Club. The names of four seniors who had been selected to receive the Faculty Award, the highest honor which may be bestowed upon an agricultural engineer at the University of Georgia, were announced by Professor Davenport. They were: H. D. Whittemore of Kankakee, Ill.; Ben C. Haynes, Jr., Chatsworth, Ga.; Ralph E. Smith, Cedartown, Ga., and William A. Balk, Augusta, Ga. These selections were made on the basis of scholarship, activity in the Club, membership in honorary societies, extra curricular activities, and character, personality, ability, and leadership.

Editors See New Bearing Plant

THE new Sandusky, Ohio, plant of New Departure, Division of General Motors Corp., was shown May 25 to a group of business paper editors as an example of a layout for modern precision production-line manufacturing.

From favorable site selection near steel sources, transportation, markets, and adequate labor; to over-all layout and detailed design for a specific manufacturing program, the plant is engineered as an instrument to shape steel into a limited range of ball bearings at maximum efficiency.

Production of bearing types and sizes ordered in large quantity in the automotive and related industries is the particular job assignment of the plant.

Starting with a completely new plant site has made it possible to avoid the compromises in layout usually necessary in expanding an existing plant. Allowance for possible future expansion has been made in locating the plant on a 140-acre plot.

With about 35 permanent key personnel from the home office and older plants of the Company, and others on temporary assignment for various periods, the plant started operation and training of local personnel in 1946, is now up to approximately 2000 personnel and aiming toward a monthly production of 2,000,000 bearings.

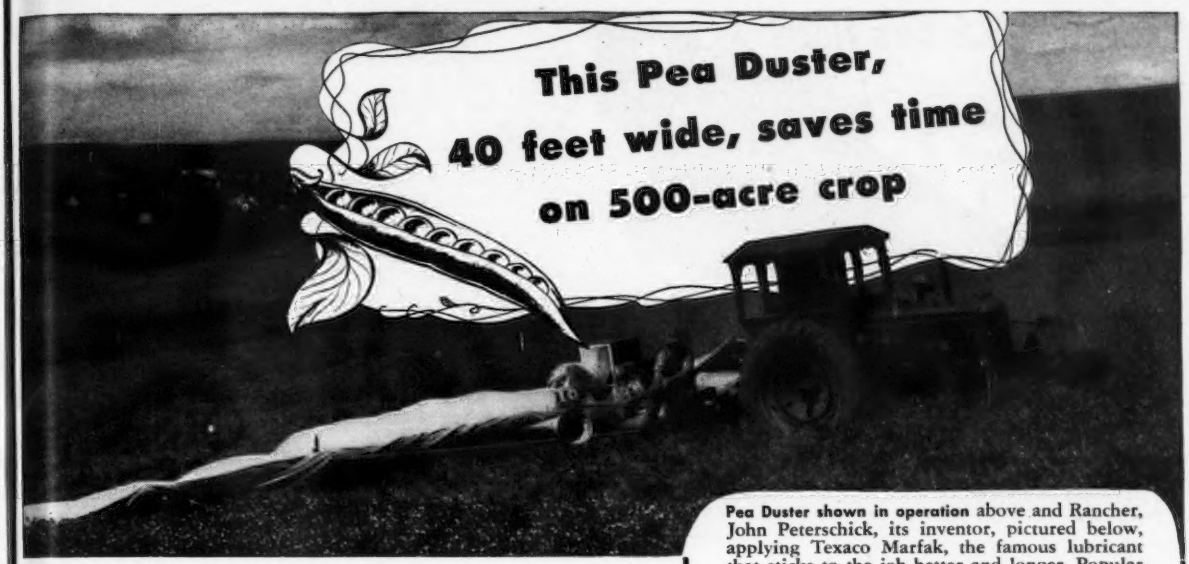
Carleton Beckwith, advertising manager of New Departure, and Lester A. Lanning, manager of the Sandusky plant, represented the Company as hosts to the visiting editors.

New Federal and State Bulletins

Literature Search on the Preservation of Foods by Freezing (First Supplement January, 1946, July, 1947) by Betty Anderson and B. H. Weil. Special Report No. 25, January, 1948 ($3.00), State Engineering Experiment Station, Georgia School of Technology (Atlanta).

A continuation, covering literature published since the beginning of 1946, of the bibliography published as Special Report No. 23 of the same station.

Portable Cleaners for Seed Grain, by G. P. Alcorn, P. C. Berryman, and R. R. Parks. California Agricultural Extension Circular 141 (Davis, March, 1948). Tells how farmers can get their seed grain cleaned and treated at reasonable cost by co-operative building and operation of portable seed cleaners.



Ingenious Rancher applies "Bedsheet Principle" to hold down Dust on Peas

John Peterschick, progressive rancher of Plaza, Washington, found that dusting 500 acres of peas was some chore, until he invented the novel pea duster shown above.

This machine enables one operator to dust four or five times as many rows at a time as was possible before — for *it dusts a swath 40 feet wide* as it moves down the field. It's a big time and labor saver. Can be easily adapted for other vegetable crops.

The dusting material is spread evenly on the peas through nozzles on two 20-foot arms extending out from trailer, making a span of 40 feet. Canvas trails behind for 20 feet holding down dust on peas for proper length of time.

Mr. Peterschick, like keen farmers and ranchers the country over, has found that it pays to farm with Texaco Products.

★ ★ ★

Pea Duster shown in operation above and Rancher, John Peterschick, its inventor, pictured below, applying Texaco Marfak, the famous lubricant that sticks to the job better and longer. Popular Texaco Man, Palmer Hayden, Rosalia, Washington, has a friendly word with John.

Mr. D. C. Buchanan (below, left), manager of Sartartia plantation, Sugarland, Texas, discusses the cotton crop with Texaco Man, L. B. Conner, while tractor driver, H. K. Williams, pours in a fresh quart of Havoline, the motor oil that *keeps engines clean,* free from power-robbing varnish and gummy sludge.

It's friendly business and a square "deal" when Texaco serves your fuel and lubrication needs. S. G. Washburn, prominent farmer of Goodwin, South Dakota, chats with popular Texaco Man, C. E. Cole, while his driver, Carl Bergan, fills the tank with Fire-Chief, the gasoline with superior *"Fire-Power."*

TEXACO
THE TEXAS COMPANY

Tune in: TEXACO STAR THEATER every Wednesday night featuring Gordon MacRae and Evelyn Knight. See newspaper for time and station.

IT PAYS TO FARM WITH TEXACO PRODUCTS

DIVISION OFFICES: Atlanta 1, Ga.; Boston 17, Mass.; Buffalo 3, N. Y.; Butte, Mont.; Chicago 4, Ill.; Dallas 2, Tex.; Denver 1, Colo.; Houston 1, Tex.; Indianapolis 1, Ind.; Los Angeles 15, Calif.; Minneapolis 2, Minn.; New Orleans 6, La.; New York 17, N. Y.; Norfolk 1, Va.; Seattle 11, Wash.
Texaco Products also distributed by McColl-Frontenac Oil Company, Limited, Montreal, Canada

The WHEELS You Need

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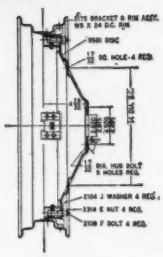
FARM TRAILERS
TRACTORS
CORN PICKERS
BALERS
DRILLS
ETC.

Are You Certain They are "SPECIAL"

The very wheel—or wheels—you require may be found in our steadily increasing line of STANDARD DISCS and HUBS. IF SO—you can SAVE on COST and DELIVERY TIME. Investigate!



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FOR LIGHT TRACTOR

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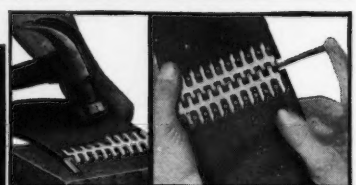
KELSEY-HAYES WHEEL COMPANY
DAVENPORT, IOWA
Wheel Builders Since 1888

BELT LACING and FASTENERS for transmission and conveyor belts



"JUST A HAMMER TO APPLY IT"

ALLIGATOR
Trade Mark Reg. U. S. Pat. Office
STEEL BELT LACING

World famed in general service for strength and long life. A flexible steel-hinged joint, smooth on both sides. 12 sizes. Made in steel, "Monel Metal" and non-magnetic alloys. Long lengths supplied if needed. Bulletin A-60 gives complete details.

FLEXCO HD
BELT FASTENERS AND RIP PLATES

For conveyor and elevator belts of all thicknesses, makes a tight butt joint of great strength and durability. Compresses belt ends between toothed cupped plates. Templates and FLEXCO Clips speed application. 6 sizes. Made in steel, "Monel Metal", non-magnetic and abrasion resisting alloys.

By using Flexco HD Rip Plates, damaged conveyor belting can be returned to satisfactory service. The extra length gives a long grip on edges of rip or patch. Flexco Tools and Rip Plate Tool are used. For complete information ask for Bulletin F-100.

Sold by supply houses everywhere

"CONVEYOR BELTS EASILY FASTENED"

FLEXIBLE STEEL LACING CO.
4077 Lexington St.
Chicago, Ill.

Personals of A.S.A.E. Members

Earl D. Anderson has joined the staff of Frank J. Zink Associates, and has been appointed Secretary of the National Sprayer and Duster Association, 4300 Board of Trade Building, Chicago. Prior to accepting this new position, Mr. Anderson was connected with Republic Steel Corporation as agricultural engineer and manager of the Agricultural Extension Bureau, since 1936. A native of Iowa, Mr. Anderson is a graduate of Iowa State College where he received his B. S. and M. S. degrees in agricultural engineering. Following graduation he accepted a position as assistant buyer in the farm equipment division of Montgomery Ward & Co., in Chicago. Later he was chief inspector and field agent for the Farmers Mutual Reinsurance Association at Grinnell, Iowa.

Kenneth V. Anderson, formerly of the farm service department of the Central Vermont Public Service Company, is now an editorial assistant on Electricity on the Farm Magazine at New York City.

T. W. Bohmker, formerly a product research engineer for Deere & Company, was recently transferred to the company's export department where he is now the division sales manager for Latin America.

Charles T. Bourns, until recently a graduate student in agricultural engineering at the A. & M. College of Texas, has been selected to head a new department of agricultural engineering at the New Mexico College of Agriculture, State College.

Robert H. Dubois has resigned as assistant professor of agricultural engineering at Kansas State College to engage in farming at Burlingame, Kan.

Herman J. Finkel has resigned his position with Consoer Townsend and Associates, to accept a position as a structural designer with the firm of Ford, Bacon, and Davis, Argonne National Laboratory, Chicago.

Earl G. Johnson has been granted a two-year leave of absence from his duties as zone conservationist (Region 3), Soil Conservation Service, U. S. Department of Agriculture, to accept appointment as senior agricultural engineer with the agricultural division of the general headquarters of the U. S. Military Government in Japan. He will be stationed at Tokyo and his duties will pertain to land reclamation and will include irrigation, drainage, land clearing, and a study of the possibilities of machinery in Japanese agriculture.

Jack R. Morris has resigned as junior agricuclturaI engineer with the U. S. Department of Agriculture, to accept a position as assistant field superintendent and agricultural engineer in the plantation department of the Hawaiian Canneries Co., Ltd. and will be located at Kapaa, Kauai, T.H.

Charles A. Rollo is now manager of the Grimes Tractor and Implement Company at Montgomery, Ala.

Vernon Selde, who has been serving as engineer at the Colville Indian Agency, Office of Indian Affairs, U. S. Department of the Interior, at Nespelen, Wash., has been transferred to the Bureau of Reclamation where he is classified as a P-2 civil engineer and is assigned to the Canal Design Section at Ephrata, Wash.

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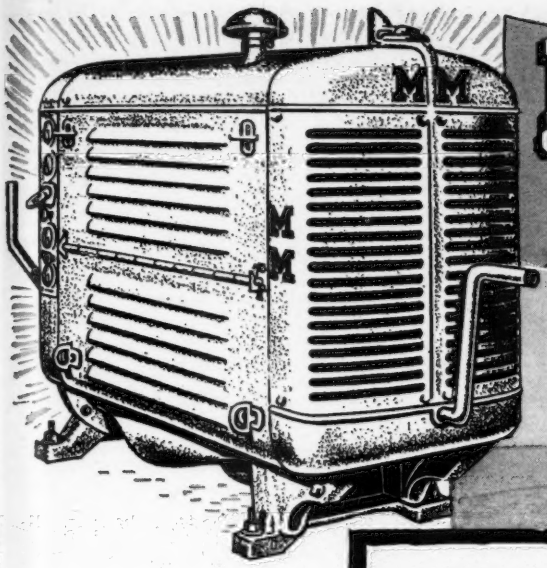
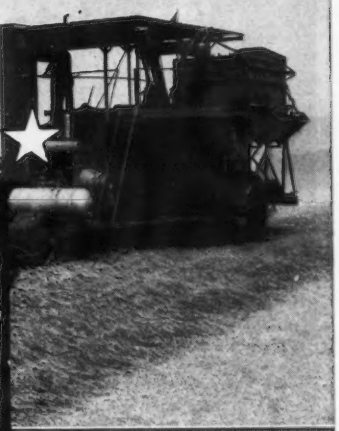
RATES: Announcements under the heading "Professional Directory" in AGRICULTURAL ENGINEERING will be inserted at the flat rate of $1.00 per line per issue; 50 cents per line to A.S.A.E. members. Minimum charge, four-line basis. Uniform style setup. Copy must be received by first of month of publication.



MINNEAPOLIS-MOLINE
MM
MODERN MACHINERY

For Profitable
POWER



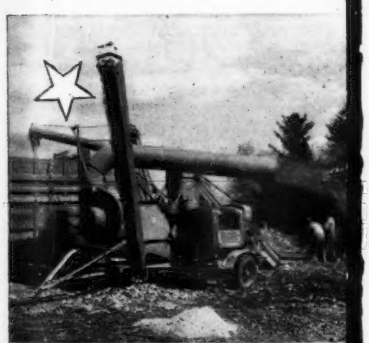
MM Engines power many large farm machines such as this old time combine.

ECONOMICAL DEPENDABILITY

Uninterrupted Power *at lower cost* is the enviable reputation established by MM Power Units on a wide variety of farm and industrial applications.

MM MODERN ENGINES FOR EXTRA FARM POWER AND PROFITS

MM Power Units are soundly engineered and ruggedly constructed to give economical, dependable service. Lower engine speeds insure longer life. Minimum service requirements provided for by easy accessibility. Pressure oiling system . . . precision bored cylinder blocks . . . high turbulence combustion chambers with controlled cooling . . . carburetion equipment for gasoline, natural gas, Butane, or distillate. Many other exclusive features recommend MM Power Units for a wide variety of farm and industrial uses.

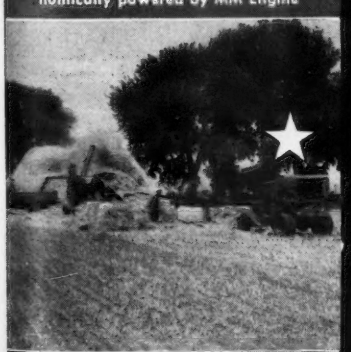


MM model E cylinder Corn Sheller economically powered by MM Engine

Many MM Power Units are used in areas where irrigation is popular.

25 H. P. TO 215 H. P. FOR

Power hay balers, combines, threshers, ensilage cutters, feed mills, corn shellers, flame cultivators, peanut hullers, potato diggers, viners, cutting wood, irrigation, sprayers, dusters, booster pumps, sprinkling systems, generators, sheep shearing, conveyors, elevators, blowers, beet loaders, etc.



A truck mounted MM Power Unit pulling a large size thresher.

MM Power Units deliver economical power on MM 12 foot Harvestors.

MINNEAPOLIS-MOLINE POWER IMPLEMENT COMPANY

MINNEAPOLIS 1, MINNESOTA, U. S. A.

One of the strongest selling statements that can be made regarding any engine-powered equipment is this:

"It's Powered with a FORD-BUILT ENGINE!"

Engines available through district sales offices of Ford Motor Company or through Ford Dealers. Universal Ford Service always available everywhere.

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FOURS · SIXES · V-EIGHTS

Write For Latest Industrial Literature

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3519 SCHAEFER ROAD · DEARBORN, MICHIGAN

Agricultural Engineers

With your research, counsel and aid, America's big soil-saving job now devolves on

The Farmers

•

This calls for tools specially designed, and engineered for the farmers' use. Ready and at hand for soil-saving when time and weather permit.

Examine the NEW

New Improved HUMMER

America's all-round soil saver! Terraces, ditches, grades. 3 wheels—2 rear drum discs. Holds records in terracing.

Martin ODEC CO. FARM TERRACERS DITCHERS, GRADERS

New Improved Model 80 IDEAL

Ruggedly built for work to *today's* highest engineering standards, by the farmer. Costing no more than ordinary farm tools. Easily operated. Saving time, labor and fuel costs on terracing, ditching, levees and dikes, leveling land.

Send for Bulletins

Illustrating these tools at work, with full details and records.

Blade suspension independent of rigid frame. Operates entirely by levers. Two rear drum discs.

OWENSBORO DITCHER & GRADER CO., Inc.

Box 50 Owensboro, Kentucky

Applicants for Membership

The following is a list of recent applicants for membership in the American Society of Agricultural Engineers. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

Abbott, Orville L. — Student in agricultural engineering, Oregon State College, Corvallis, Ore.

Brevick, Harold L. —Research fellow in agricultural engineering, University of Idaho, Moscow, Idaho.

Brumfield, Charlie F. — Rural electrical development, Tennessee Valley Authority, 500 Empire Bldg., Knoxville, Tenn.

Channing, James B. — Managing secretary, Pacific Northwest Hardware & Implement Assn., Spokane, Wash. (Mail) P. O. Box No. 6.

Clarke, Roland W. — Sales manager, Western Regional Sales Co. (Mail) R. R. No. 4, Box 720, Portland 2, Ore.

Ewing, James R. — Field instructor, Dearborn Motors Corp., 15050 Woodward Ave., Detroit 3, Mich.

George, Robert M. — Student in agricultural engineering, University of Missouri. (Mail) Hardin, Mo.

Hamsher, Richard C. — Farm representative, Pennsylvania Power & Light Co., Harrisburg, Pa. (Mail) 3001 North 4th St.

Hockey, W. S. — Assistant chief designer (agricultural machinery), Dening & Company (1937) Ltd., Somerset Works, Chard, Somerset, England. (Mail) 2 Morely Villas, Crimchard.

Kern, A. G., Jr. — Owner and manager, Strong Stock Farm, R. R. 5, Knoxville, Tenn.

Lange, Oscar C. — Farm representative, Pennsylvania Power & Light Co. (Mail) Millersburg, Pa.

Larose Paul E. — Graduate student in agricultural engineering, Virginia Polytechnic Institute, Blacksburg, Va. (Mail) University Club.

Loring, Malcolm S. — Agricultural engineer, Portland Cement Assn. (Mail) 1528 Walnut St., Philadelphia, Pa.

Millier, William F. — Research assistant in agricultural engineering, Cornell University, Ithaca, N. Y.

Phillips, William J. — Director, castings development dept., Steel Founders Society of America, 920 Midland Bldg., Cleveland, Ohio.

Richardson, Boone Y. — Graduate student in agricultural engineering, Louisiana State University, Baton Rouge 3, La. (Mail) 7015 University Station.

Rust, Albert E. — Rural service engineer, Public Service Co. of Northern Illinois. (Mail) Box 278, Glencoe, Ill.

Sastry, C. P. — Graduate student in agricultural engineering, University of Minnesota, University Farm, St. Paul 1, Minn.

Sleigh, E. B. — Technical salesman, Shell Oil Co. of British Columbia, Ltd., Stock Exchange Bldg., Vancouver, B. C., Canada.

Thornton, J. F. — Student in agricultural engineering, Alabama Polytechnic Institute, Auburn, Ala. (Mail) 340½ East Mag.

Whiteman, Morris — Secretary-treasurer and research assistant, Rural Housing Advisory Committee for British Columbia, University of British Columbia, Vancouver, B. C., Canada. (Mail) 3175 W. 4th Ave.

Transfer of Grade

Hill, H. O. — Superintendent, Bluebonnet Farm,, Texas Agricultural Experiment Station, McGregor, Tex. (Member to Fellow)

Kirk, Dale E. — Assistant professor of agricultural engineering, Oregon State College, Corvallis, Ore. (Junior Member to Member)

Moore, Samuel T., Jr. — Vocational instructor, South Hill High School, South Hill, Va. (Junior Member to Member)

Munter, Ernest L. — Agricultural engineer, Wm. Gehring Farm, Rensselaer, Ind. (Junior Member to Member)

Rodman, Earl J. — Manager, Raleigh Farm Equipment Co., Raleigh, N. C. (Mail) Box 2250 (Junior Member to Member)

Winkelblech, Carl S. — District soil conservationist, Soil Conservation Service, USDA. (Mail) Box 441, Batavia, N.Y. (Junior Member to Member)

New Federal and State Bulletins

The Effectiveness of Roofing Nails for Application of Metal Building Sheets, by Henry Giese and S. Milton Henderson. Research Bulletin 355 (November, 1947), Agricultural Engineering Section, Iowa Agricultural Experiment Station. Engineering report of withdrawal resistance under service conditions.

Mechanization of Cotton. Special report to the Cotton Subcommittee, House (of Representatives) Agricultural Committee, by the division of mechanical processing of farm products and the division of farm machinery, BPISAE, Agricultural Research Administration, U.S. Department of Agriculture.

This summarizes the engineering problems, present status and progress, and recommendations for further action on the subject.

● *Built by* **AEROVENT FAN CO.**, *this* SKF *-equipped fan circulates air through hay as it lies in the barn. Tests on protein content of barn-cured hay run as high as 20% instead of the usual 10% or 11% found in field-cured hay.*

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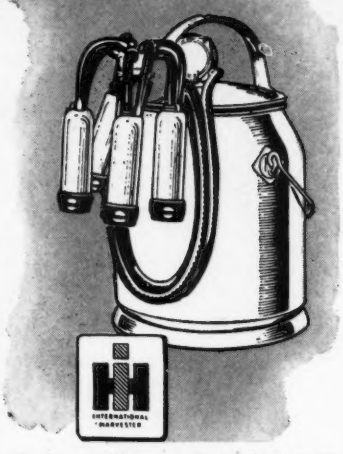

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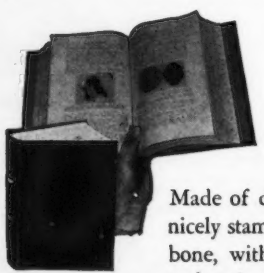

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Personnel Service Bulletin

The American Society of Agricultural Engineers conducts a Personnel Service at its headquarters office in St. Joseph, Michigan, as a clearing house (not a placement bureau) for putting agricultural engineers seeking employment or change of employment in touch with possible employers of their services, and vice versa. The service is rendered without charge, and information on how to use it will be furnished by the Society. The Society does not investigate or guarantee the representations made by parties listed. This bulletin contains the active listing of "Positions Open" and "Positions Wanted" on file at the Society's office, and information on each in the form of separate mimeographed sheets, may be had on request. "Agricultural Engineer" as used in these listings, is not intended to imply any specific level of proficiency, or registration, or license as a professional engineer.

NOTE: In this Bulletin the following listings still current and previously reported are not repeated in detail. For further information see the issue of AGRICULTURAL ENGINEERING indicated.

POSITIONS OPEN: 1947 APRIL—O-552. SEPTEMBER—O-581. DECEMBER—O-604. 1948 JANUARY—O-605, 606. MARCH—O-611. APRIL—O-612, 613, 614, 615. MAY—O-617.

POSITIONS WANTED: 1947 SEPTEMBER—W-119. 1948 JANUARY—W-137. MARCH—W-145, 146, 147, 148, 150, 152. APRIL—W-155, 156, 158, 159, 161. MAY—W-166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176.

NEW POSITIONS OPEN

AGRICULTURAL ENGINEER (professor or associate professor) for research on field machinery for tobacco production in a state college in the Southeast. MS deg in agricultural engineering, or equivalent. Require good knowledge of machinery, and research experience. Familiarity with tobacco growing desirable. Usual personal qualifications for public service research. Excellent opportunity for advancement. Age 24-35. Salary $5,000, for 11 months. O-618

AGRICULTURAL ENGINEER (instructor) to teach farm power, rural electrification and other agricultural engineering courses in a southwestern college specializing in Smith-Hughes teacher training. MS deg preferred, but will consider man with BS deg in agricultural engineering. Practical experience in motor mechanics required. Desire good co-operator with interest and initiative in helping to build an agricultural engineering department. Excellent opportunity for advancement. College staff apartment available at reasonable cost. No particular age preference. Salary open. O-619

AGRICULTURAL ENGINEER (assistant professor) to inaugurate research program in irrigation engineering in agricultural engineering department in Pacific land-grant University. MS deg in engineering, or equivalent, research experience, irrigation background; knowledge of other agricultural engineering fields an asset. Salary $3780 to $4740 plus $576 bonus. Housing situation and nature of bonus described upon application. O-620

AGRICULTURAL ENGINEER (junior vocational instructor) for teaching agricultural mechanics and agricultural engineering in a western state college. BS deg in agricultural engineering required. Higher degree preferred. Want man with farm background, and some experience in farm equipment business, college or vocational teaching, research, irrigation, or soil conservation. Should be qualified to handle courses for agriculture teachers during summer session. Desirable schedule of salary advancement and opportunity to grow with program. Age 25-45. Salary $325 per mo to start. O-621

IMPLEMENT DESIGN ENGINEER for development work on tillage and haying implements with large full-line manufacturer in Midwest. BS deg in agricultural or mechanical engineering. Approximately 5 yr experience in implement design. Salary open. O-622

AGRICULTURAL ENGINEER (extension specialist) in soil and water or farm structures field, in corn belt state. BS deg in agricultural engineering or equivalent required. Opportunity provided for development in subject matter and extension techniques. Opening to be filled as soon as possible. Salary open. O-623

NEW POSITIONS WANTED

AGRICULTURAL ENGINEER desires design, development, service, research, extension or graduate assistantship in power and machinery or soil and water field. BS deg in agricultural engineering, June, Michigan State College. Farm background. Topographic draftsman, one year. Army meterologist 2 yr. No disability. Available June. Married. Age 26. Salary open. W-178

AGRICULTURAL ENGINEER desires research or project work in soil and water field, or development work in power and machinery. BS deg in agricultural engineering, 1943, Kansas State College. Farm background. Student assistant in research projects, 1½ yr. Engineering in tractor works, 4¼ yr, including drafting, shop, experimental, and test work on materials, development work on new tractors and electrical equipment. No disability. Available on 2 to 3 weeks notice. Single. Age 27. Salary open. W-179

AGRICULTURAL ENGINEER desires teaching, research, or management position in rural electric field. Professional agricultural engineering degree, 1939, Washington State College. Advanced study toward PhD degree. Varied teaching, research, extension, and engineering practice. 14 yrs. No disability. Available July 1. Married. Age 37. Salary open. W-180

FARM MANAGER and appraiser desires work in finance, development, sales, research, or service with private company serving agriculture. BS deg in agriculture, 1928, Purdue University. Extended experience with loan division of an insurance company, in farm rehabilitation, management, appraisal, sales, and loan service, in Midwest. No disability. Available immediately. Married. Age 43. Salary, $5000 range. W-181

AGRICULTURAL ENGINEER desires work in farm structures field in commercial organization or extension service. BS deg in agriculture 1947, and in agricultural engineering 1948, Ohio State University. Farm background, and miscellaneous part time work while in college. War commissioned service in Air Corps. No disability. Available July 1. Married. Age 24. Salary open. W-182